RAA270005KFP

General Purpose Power Management IC

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Description

The RAA270005KFP is a general-purpose Power Management IC (PMIC), and suitable for RENESAS RH850/P1x series microcontroller (MCU). The features and the details of the PMIC are described in this document.
The PMIC contains two types of DCDCs converters: buck and boost, two low dropout linear regulators (LDO) and two linear trackers.
The switching frequency of boost/buck DCDCs are typical 420 kHz, 2.1 MHz respectively.
Monitor functions for the internal status are implemented. Input voltage, output of all regulators, and internal analog voltage corresponding to temperature can be monitored through ADC of MCU. And reference voltage can be monitored for testing the ADC of MCU as well.
The PMIC has sequencer circuits for controlling power-up/down, therefore any external sequencer circuits are unnecessary. And the PMIC can control an external backup-power for MCU.

Features

- Supply the power to Renesas RH850/P1x (eVR)
- Load dump robustness
- Input voltage range: 6.6~18.5V to perform specified characteristics.
  5.4V~: continued operation without low voltage detection
  3.8V~: continued operation declined the output voltage
  * If not use the boost DCDC converter
- DCDC converter:
  Boost: 6.0V/250mA (Input voltage: 2.2V~)
  Buck: 6.1V/600mA
- Linear regulators:
  1. Output voltage : 3.3V/10mA
  2. Output voltage : 5.0V/350mA with reverse protection
- Two linear trackers
  Output voltage: VOUT1/100mA with reverse protection
- Automatic power sequence
- An external backup-power control
- Watchdog timer
- Analog multiplexer
- Interrupt request
- Thermal shut down
- Reset generator
- External devices control
- Monitoring to a core voltage in MCU.
- Exposed die pad, HLQFP package, 40pin 9mm x 9mm

Application

- Automotive applications
- Industrial applications

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1. Abusolute maximum ratings

Item	Comment	Min	Max	unit
VINR, VINPDC	Battery	-0.3	28 Note3	V
VIN3V	Supply power for internal circuits	-0.3	19	V
VDDIO, VINPBS	Supply power for PMIC, I/O	-0.3	6.5	V
VINP1, VINPTRQ	Regulator input	-0.3	19	V
AGND1~3	Ground	-0.3	0.3	V
LX		-1.0Note2	VINPDC+0.3 Note6	V
FBDC	Feedback pin for DCDC	-0.3	19	V
BSGATE		-0.3	VINPBS+0.3 Note5	V
ENIG		-0.3	VINR+0.3 Note6	V
AMUXIN1/2		-0.3	VINR+0.3 Note4	V
VOUT0	LDO0 output	-0.3	VINR+0.3 Note4	V
VTRQ1/2	TRACK1/2 output	-0.3	19	V
VOUT1	LDO1 output	-0.3	6.5	V
MUXOUT, BUFREF		-0.3	VOUT1+0.3 Note5	V
COREMON		-0.3	6.5	V
BKCNT, CSGND, CSR		-0.3	VIN3V+0.3 Note5	V
ERROR, WDI	Digital input pins	-0.3	6.5	V
EN, SPICSB, SPICLK, SPISDI	Digital input pins	-0.3	VDDIO+0.3 Note5	V
EXCNT1/2, SPISDO, SUSP, INTOUT, RSTB	Digital output pins	-0.3	VDDIO+0.3 Note5	V
TEST1/2		-0.3	VIN3V+0.3 Note5	V
Thermal resistance (Typical)	Junction to ambient	20.2 Note7		°C/W
	Junction to case (Top)	33.3 Note7		
	Junction to case (Bottom)	1.03 Note7		
Junction Temperature Note8		-40	150	°C
Storage Temperature Range		-55	150	°C

Notes 1. Stress beyond those listed under Absolute Maximum Rating may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device liability and lifetime.

2. Not allowed to apply continuous voltage.

3. Maximum voltage is 40V under load dump condition. (Duration time is 400ms.)

4. Must be 19V or lower.

5. Must be 6.5V or lower.

6. Must be 28V or lower.

7. Simulation value based on JEDEC-2S2P condition.

8. The PMIC includes over temperature protection that is intended to protect the device during momentary over load condition. Junction temperature will exceed the maximum operating junction temperature when over temperature is achieved. Continuous operating above specified maximum operating junction temperature may impair device reliability.

2. Pin Configuration

2.1. Pin Configuration

Pin configuration is shown in the below figure. The package is 40pin exposed die pad HLQFP.

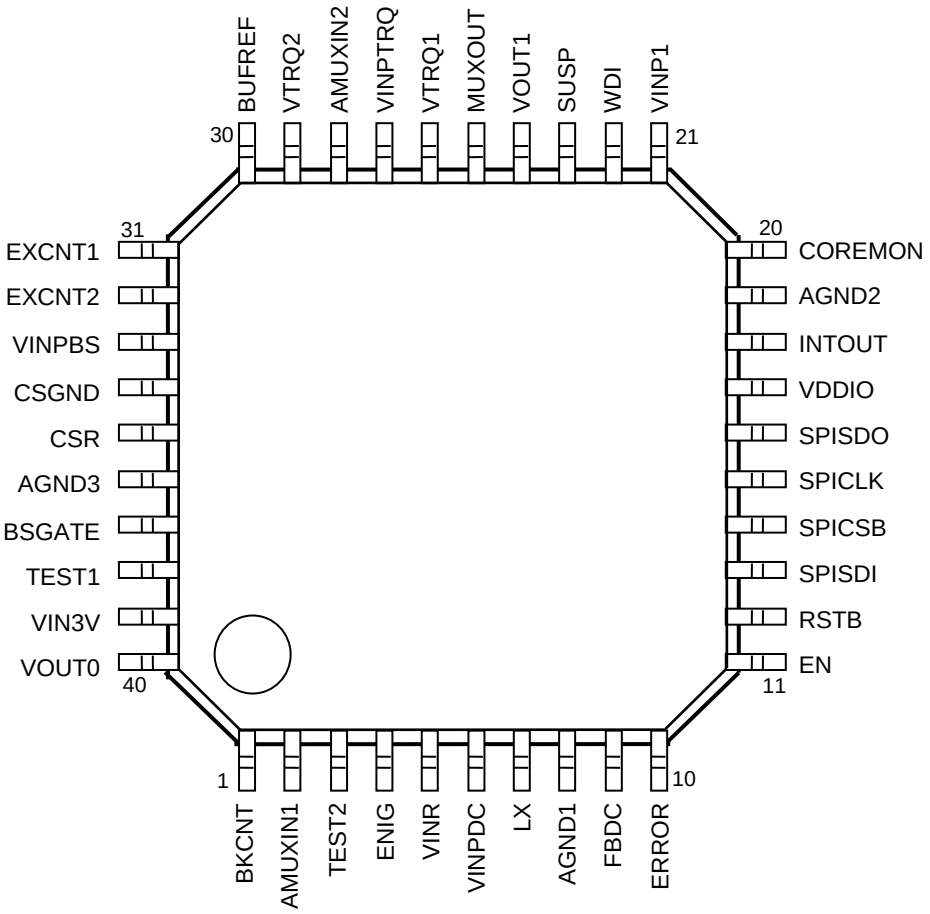


Figure 2-1 Pin configuration (Top view)

2.2. Pin list

The pin list table is shown below.

Pin #	Pin name	Pin function	Analog/ Digital	I/O/P/G	Interface level	Protect circuit		Remarks
						VDD name	GND name	
1	BKCNT	Backup-power control	Digital	Output	CMOS	VIN3V	AGND1	
2	AMUXIN1	Analog multiplexer input1	Analog	Input	-	-	AGND3	
3	TEST2	For test	-	-	-	VIN3V	AGND1	Connect to Ground
4	ENIG	Power enable of the PMIC	Digital	Input	NMOS	VINR	AGND1	Included pull-down resistor
5	VINR	Power supply for LDO0	-	Power	-	-	AGND1	Connect to battery
6	VINPDC	Buck DCDC input	-	Power	-	-	AGND1	Connect to battery
7	LX	Driver output for an external inductor	Analog	Output	-	-	AGND1	
8	AGND1	Ground	-	-	-	-	-	
9	FBDC	Buck DCDC feed-back input	Analog	Input	-	-	AGND1	
10	ERROR	Monitoring input from MCU	Digital	Input	-	-	AGND1	Included pull-down resistor
11	EN	Power enable of the PMIC	Digital	Input	CMOS	VDDIO	AGND1	Included pull-down resistor
12	RSTB	Reset output	Digital	Output	Open drain	VDDIO	AGND1	Included pull-up resistor
13	SPISDI	Serial interface, data input	Digital	Input	CMOS	VDDIO	AGND2	Included pull-down resistor
14	SPICSB	Serial interface, chip select	Digital	Input	CMOS	VDDIO	AGND2	Included pull-up resistor
15	SPICLK	Serial interface, clock input	Digital	Input	CMOS	VDDIO	AGND2	Included pull-down resistor
16	SPISDO	Serial interface, data output	Digital	Output	CMOS	VDDIO	AGND2	
17	VDDIO	Power supply for digital IO part of the PMIC	-	Power	-	-	AGND2	
18	INTOUT	Interrupt signal output	Digital	Output	CMOS	VDDIO	AGND2	
19	AGND2	Ground	-	-	-	-	-	
20	COREMON	Monitoring to a core voltage in MCU	Analog	Input	-	-	AGND2	

Pin list (Continued)

Pin #	Pin name	Pin function	Analog/ Digital	I/O/P/G	Interface level	Protect circuit		Remarks
						VDD name	GND name	
21	VINP1	Power supply for LDO1	-	Power	-	-	AGND2	
22	WDI	Clear watch dog timer	Digital	Input	CMOS	-	AGND2	Included pull-down resistor
23	SUSP	Low voltage indicator of LDO1	Digital	Output	CMOS	VDDIO	AGND2	
24	VOUT1	LDO1 output	Analog	Output	-	-	AGND2	
25	MUXOUT	Analog multiplexer output	Analog	Output	-	VOUT1	AGND2	
26	VTRQ1	TRACK1 output	Analog	Output	-	-	AGND2	
27	VINPTRQ	Power supply for TRACK2	-	Power	-	-	AGND2	
28	AMUXIN2	Analog multiplexer input2	Analog	Input	-	-	AGND3	
29	VTRQ2	TRACK2 output	Analog	Output	-	-	AGND2	
30	BUFREF	Reference voltage output	Analog	Output	-	-	AGND2	Connect to 0.1µF
31	EXCNT1	Specified digital output1	Digital	Output	CMOS	VDDIO	AGND3	
32	EXCNT2	Specified digital output2	Digital	Output	CMOS	VDDIO	AGND3	
33	VINPBS	Power supply for boost DCDC	-	Power	-	-	AGND3	
34	CSGND	Current detection1 for boost DCDC	Analog	Input	-	-	AGND3	Detection resistor, low voltage side
35	CSR	Current detection2 for boost DCDC	Analog	Input	-	-	AGND3	Detection resistor, high voltage side
36	AGND3	Ground	-	-	-	-	-	
37	BSGATE	Boost switching control	Analog	Output	-	VINPBS	AGND3	External transistor control
38	TEST1	For test	-	-	-	VIN3V	AGND1	Connect to ground
39	VIN3V	Power supply for the internal circuit	-	Power	-	-	AGND3	
40	VOUT0	LDO0 output	Analog	Output	-	VINR	AGND3	

3. Internal Block Diagram

The PMIC block diagram is shown in the below figure.

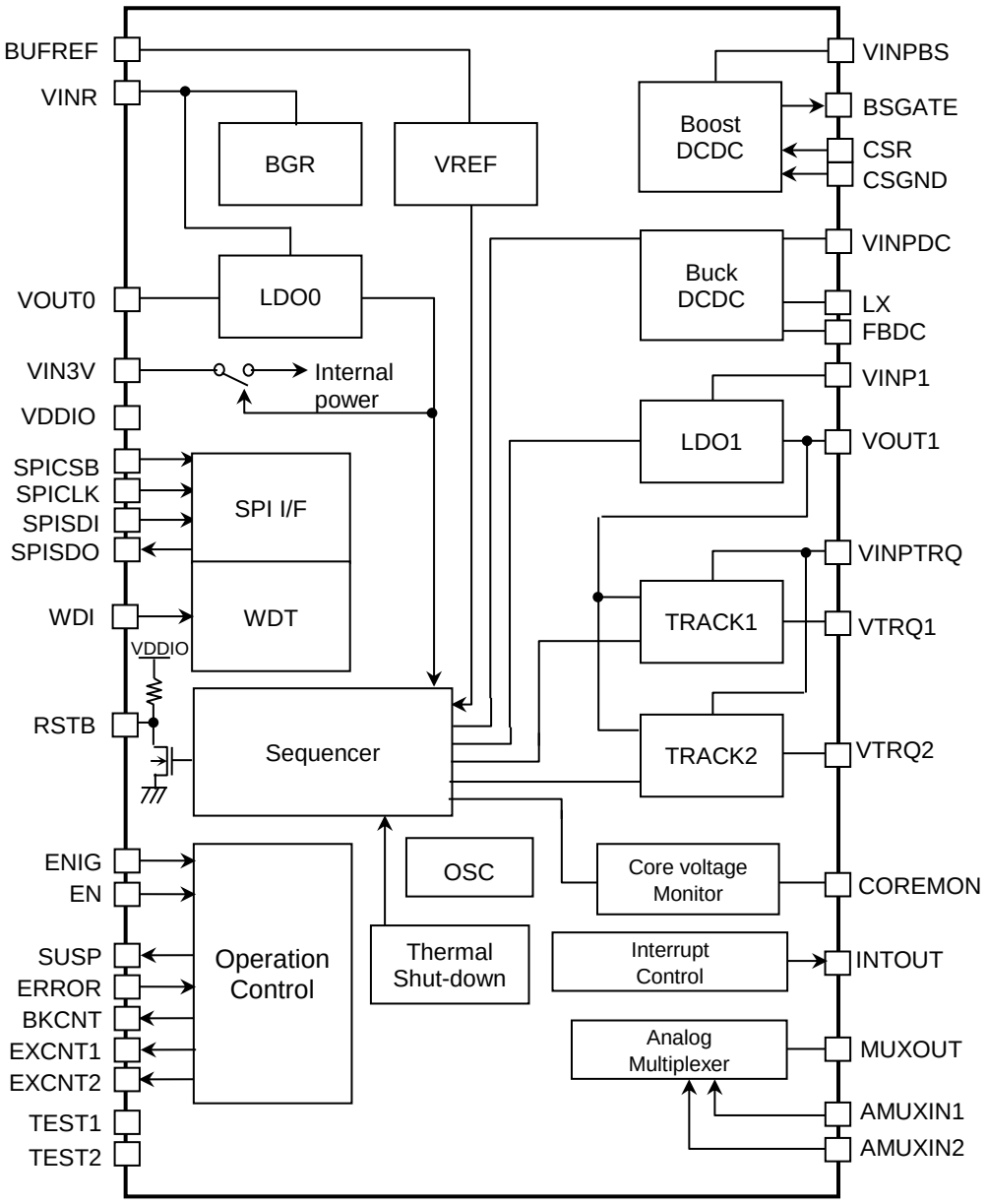


Figure 3-1 The PMIC block diagram

The abstractive descriptions are here. Refer to each section for more details.

- **Boost DCDC**
  Boost DCDC is a switching regulator which boost up to 6.0V, and the frequency is 420 kHz.
- **LDO0**
  LDO0 is a low drop output regulator which generates 3.3V power. The output current ability is 10mA.
- **LDO1**
  LDO1 is a low drop output regulator which generates 5.0V power. The output current ability is 350mA.
- **TRACK1**
  TRACK1 is a voltage tracker. The output tracks a voltage applied on VOUT1. The current ability is 100mA.
- **TRACK2**
  TRACK1 is a voltage tracker. The output tracks a voltage applied on VOUT1. The current ability is 100mA.
- **Buck DCDC**
  Buck DCDC is a switching regulator which generates 6.1V, and the frequency is 2.1 MHz. The output current ability is 600mA.
- **Band gap reference (BGR)**
  BGRs generate reference voltages for each regulator.
- **VREF**
  VREF generates reference voltages for regulators. An external capacitor is necessary to reduce noise of LDO1.
- **Analog multiplexer**
  An analog multiplexer outputs internal analog voltage of the PMIC or external pins (AMUXIN1/2).
- **SPI interface**
  SPI receives requests from MCU, or sends register setting.
- **Watch dog timer (WDT)**
  WDT monitors system operating, can be controlled by WDI pin or via SPI.
- **Sequencer**
  Sequencer controls power up/down of the regulators.
- **Operation control**
  Operation control for the PMIC and external pins.
- **Interrupt control**
  Interrupt operation control.
- **Oscillator**
  Oscillator for sequencer, buck DCDC and boost DCDC.
- **Thermal shutdown**
  Thermal shutdown monitors the temperature in the PMIC. If the internal temperature exceeds the shutdown temperature, the PMIC goes to P/D sequence2.
- **Core voltage monitor**
  Core voltage monitor detects the under or over voltage of MCU’s core voltage.

4. PMIC Function

4.1. Abstract of the PMIC

In order to supply power to MCU or ASIC, the PMIC contains current mode DCDC converters (DCDC) and two LDOs. The buck DCDC's output is used for LDO1's or trackers power source. When a battery voltage is applied to the PMIC, the regulators rise up automatically in accordance with designated sequence. And after all outputs of the regulators power up successfully, the "INTOUT" signal is released. The PMIC also has a watchdog timer (WDT). When timer in the WDT expires, a reset signal is occurred. The WDT is refreshed by a request via WDI pin or SPI.
When the junction temperature reaches over Tsd, a reset occurs and the all regulators except for LDO0 is forced to power down immediately

4.1.1. PMIC Operation

The principal operate transitions and conditions are illustrated in the below state diagram.
ENIG or EN is enables operation of the PMIC.

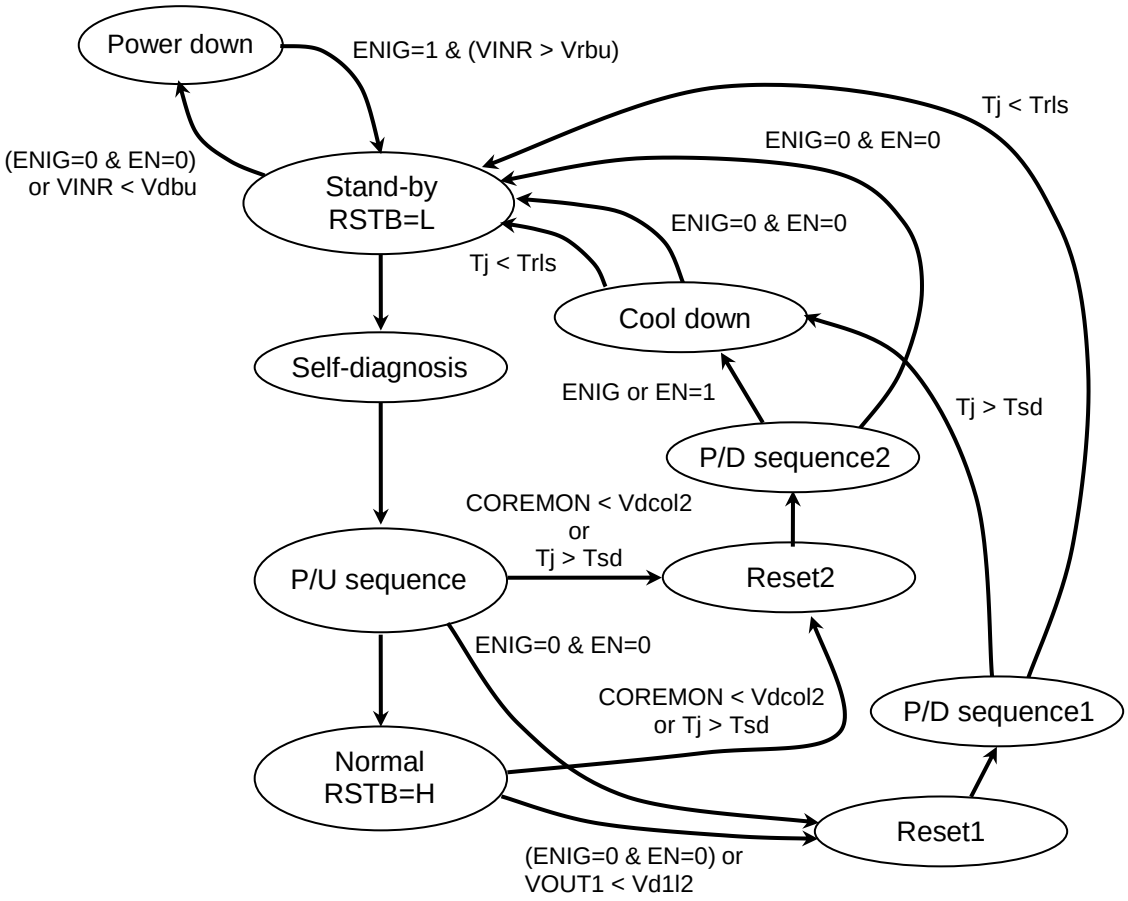


Figure 4-1 State diagram

- **Power down**
  In this state, no blocks in the PMIC operate.
- **Stand-by**
  In this state, the PMIC executes initial reset of internal registers and RSTB pin is asserted low. Only LDO0 is activated by ENIG=1 operates in this state.
- **Self-diagnosis**
  Self-diagnostic automatically is started after stand-by state. In this state, over/low voltage detector in the regulators, the temperature sensor and the internal logic circuit are checked.
- **P/U sequence**
  After executing self-diagnostic, this state is automatically entered. Even if one of regulators doesn't rise up, the PMIC stays in this state. After LDO1 rise up, INTOUT is high and passed 14.5ms, a reset is released.
- **Normal**
  After the reset is released, this state is automatically entered. The system monitor is started with using the WD function. And also, the PMIC monitors the junction temperature and the output voltage of VOUT1.
- **Reset1b**
  RSTB asserts low by setting low both ENIG and EN, or low voltage detection of VOUT1 immediately.
- **P/D sequence1**
  This state is automatically entered after "Reset 1" state. Buck DCDC and LDO1 start to fall down in designated order. The junction temperature is checked. If the junction temperature is higher than Tsd, then the PMIC enters "Cool down" state. If lower than Trls, the PMIC enters back "Stand-by" state.
- **Reset2**
  When the junction temperature comes over Tsd or the low voltage of core voltage is detected, the reset is released.
- **P/D sequence2**
  This state is automatically entered after "Reset2" state. Buck DCDC and LDO1 start to fall down in designated order. When ENIG or EN is set to high, the PMIC goes to "Cool down" state. When ENIG and EN are set to low, the PMIC goes to "Stand-by" state.
- **Cool down**
  The PMIC checks if the junction temperature is lower than Trls. If the junction temperature is higher than Tsd, the PMIC waits until the junction temperature cools down. After the junction temperature comes below Trls, the PMIC enters "Stand-by" state. When ENIG and EN are set to low, the PMIC also goes to "Stand-by" state.

4.1.2. Pin setting

The PMIC has ENIG and EN pin to define PMIC operation. For proper operation, these pins should be set to the appropriate level. The appropriate setting voltages are described in "6. Electrical Characteristics"

- **PMIC enabling**

The PMIC enabling is set by ENIG or EN pin. And in the initial phase, the PMIC should be enabled on by ENIG. ENIG pin can be connected to a battery voltage.

Table 4-1 PMIC operation setting

ENIG	EN	PMIC operation
0	0	PMIC disable
0	1	PMIC enable
1	0	PMIC enable
1	1	PMIC enable

4.1.3. Configuration register

In order to configure function of the PMIC, need to set in this register. Refer to each described section for more setting information.

- Configuration register
  The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

  - Address (CONF): 10H

A5	A4	A3	A2	A1	A0
0	1	0	0	0	0

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	RSTMD	-	RSTERR	SPIWDT	ADVWD

  - Setting contents

Register name		Control contents	Setting	
			1	0
RSTMD	D4	Reset mode	L	Pulse *
RSTERR	D2	Reset assertion by ERROR	On	Off *
SPIWDT	D1	Select WDT clear input channel	SPI	WDI *
ADVWD	D0	Advanced mode for WD operating	On	Off *

* Default setting

Note: Advanced mode for WD is effective when SPI is selected to refresh WDT.

RSTMD: Reset mode select when a reset is occurred.
RSTERR: Reset control register by ERROR. After setting “On”, RSTB asserts low when ERROR indicates error.
SPIWDT: select WDT clear input
ADVWD: This register can set to operate WDT in advanced mode. After setting “Enable”, WD operates in advanced mode. Refer to section 4.8.3.

4.1.4. Product code

These bits identify the PMIC product code.

- Product code
  - Address(CHIPID): 00H

A5	A4	A3	A2	A1	A0
0	0	0	0	0	0

  - Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
1	0	0	0	0	0	1	0

4.2. Serial Interface

The PMIC includes serial to peripheral interface (SPI). Refer to each section for more detail contents,

- WDT operation (If SPI control is selected)
- Control the monitor function
- Reset control, read reset factor, write reset clear/mask
- Interrupt control, read interrupt factor, write interrupt clear/mask
- Tracker control
- Change thermal detection

4.2.1. Signal format

The bit length of the communication is 16bits, and the signal format is illustrated in below figures.
The data should be transmitted as MSB first. For this SPI, one SPICSB active is for one request. Therefore, SPICSB should be high after transmitted data.

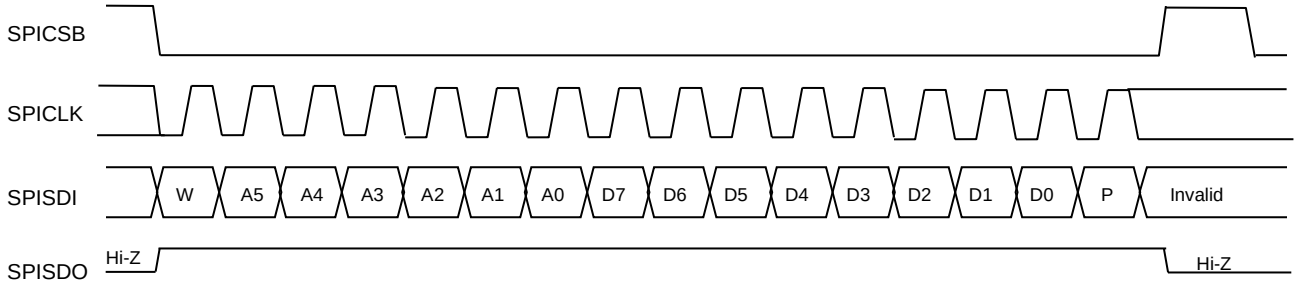


Figure 4-2 SPI format (Write)

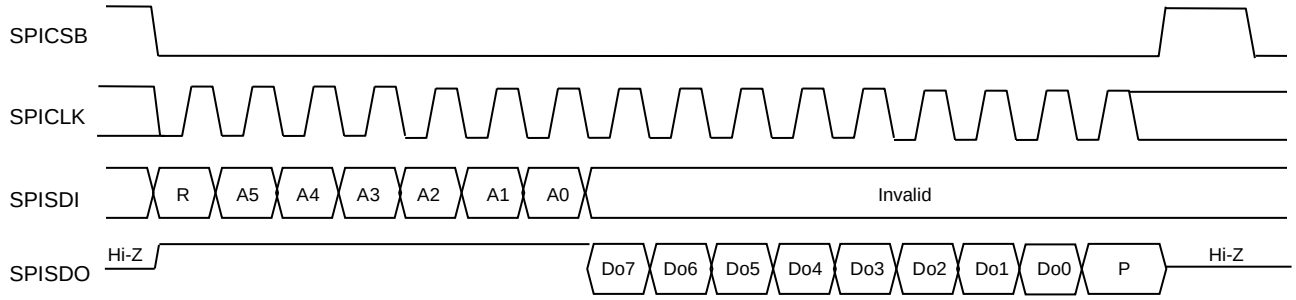


Figure 4-3 SPI format (Read)

Caution: The entered data is latched by rising edge of SPICSB.

- **W/R**
  This bit indicates write or read register. To write register, bit W/R should be set 0. To read register, bit W/R should be set 1. When read register, Do7-Do0 bits indicate contents. (D7-D0 bits are ignored in the PMIC.)
- **A5-A0**
  The PMIC contains several registers. The addresses are described in these bits. Every register can be read to confirm its content.
- **D7-D0**
  These bits describe control bits of the PMIC to write into the PMIC.
- **Do7-Do0**
  These bits describe content bits or flag bits to read from the PMIC. SPISDO pin keeps Hi-z during transmitting “W/R” bit and address bits, A5-A0. The parity bit of read data is calculated with “W/R” bit and all address bits as 1.
- **P**
  This bit indicates a parity bit calculated based on the number of logic contained in bits excepting parity bit itself.

  Bit P has to be set 0 if the number of 1 is odd.
  Bit P has to be set 1 if the number of 1 is even.

  Note: If interrupt factors of the target address occurs during the interrupt factor reading, the parity bit might not be set correctly.

4.2.2. Ensuring communication

To ensure the communication between the PMIC and MCU, the PMIC observes the SPI signal of following accesses. If any violation, The PMIC ignores this command or request.

- Number of SPICLK
  The PMIC counts SPICLK clocks while SPICSB is low. If the number of clock is not 16, that communication is considered as an error. The PMIC ignores this command or request.
- Undefined address
  When undefined address is transmitted, the PMIC ignores this address’ contents.
- Parity bit
  The SPI format includes a parity bit. The PMIC monitors the parity bit and if transmitted bits are not based on the parity bit, this communication is considered as an error. The PMIC ignores this command or request.

4.2.3. Secured request

A MCU read PRTCT register to get key and write it back to PRTCT register before modifying those secured registers, instead of writing the key to those secured registers. Without the key code, the request is ignored.

- Pin setting (Address: 02H)
- Interrupt mask register (Address: 0CH~0FH)
- Configuration register (Address: 10H)
- Reset mask register (Address: 14H)
- Window time setting for WDT (Address: 17H)
- Tracker register (Address: 1AH)
- Buck DCDC protection setting (Address: 1BH)
- Software reset (Address: 1DH)
- Temperature setting for the thermal shut down (Address: 1EH)
- Boost DCDC protection setting (Address: 1FH)

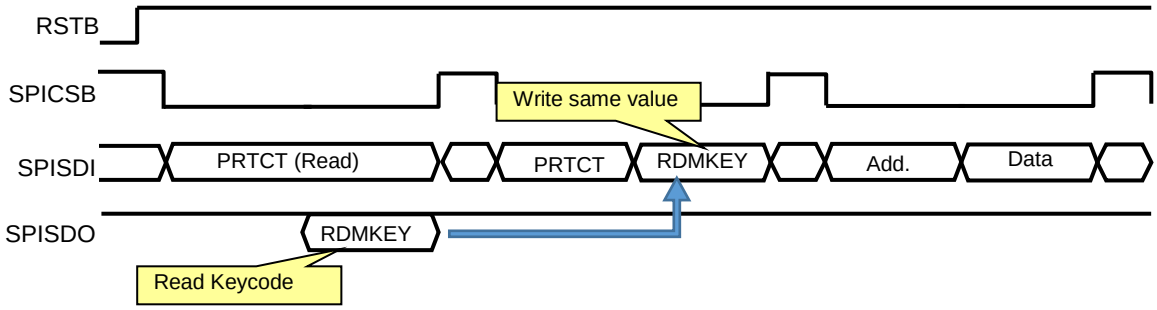


Figure 4-4 Key code unlock

4.2.4. Register

The contents of SPI setting are described in this section.

- Protect deactivate key code
  - Address (PRTCT): 11H

A5	A4	A3	A2	A1	A0
0	1	0	0	0	1

  - Register

    Before the access secured registers, need to obtain the below random code by read mode.

Do7	Do6	Do5	Do4	Do3	Do2	Do1	Do0
RDMKEY (Do7:Do0)							

    Need to enter the obtained data before MCU enters request.

D7	D6	D5	D4	D3	D2	D1	D0
RDMKEY (D7:D0)							

  - Setting contents
    - RDMO (Do7:Do0): Random code from the PMIC
    - RDMI (D7:D0): Copy and sent RDMO (Do7:Do0)

4.2.5. Register map

The registers which can be set in the PMIC are summarized in below table with its address and data. The detail contents are described in each section. Hexadecimal number is written as xxH.

Address	Register Name	R/W	D7	D6	D5	D4	D3	D2	D1	D0	Initial	Secured	Reset by	Function
00H	CHIPID	R	CHIPID<7:0>								82H			Chip ID
02H	SETDPIN	R/W	---	---	---	---	SETEXCNT2	SETEXCNT1	SETSUSP	SETBKCNT	02H	O	RSTB	Set / Read for digital output pins
03H	INTFAC	R	---	---	INTRSFG	INTSD	INTR4	INTR3	INTR2	INTR1	00H		DET0O	Interrupt factor
04H	INTREQ1	R	DETTRQ2OC	DETTRQ1OC	DETBSOC	DETCOL	DETTRQ2L	DETTRQ1L	DET1L	DETDCL	00H		DET0O	Interrupt request 1
05H	INTREQ2	R	---	---	DETCOU2	DETCOU1	DETTRQ2U	DETTRQ1U	DET1U	DETDCU	00H		DET0O	Interrupt request 2
06H	INTREQ3	R	BKMODE	SDBKUP	SDSTA	SDOSC	BATBK	DETREF	WRTMP	DETDCOC	00H		DET0O	Interrupt request 3
07H	INTREQ4	R	DUMMY	---	---	PEXCNT2	PEXCNT1	PSUSP	PBKCNT	PRSTB	00H		DET0O	Interrupt request 4
08H	INTCL1	W	CLTRQ2OC	CLTRQ1OC	CLBSOC	CLCOL	CLTRQ2L	CLTRQ1L	CL1L	CLDCL	-		RSTB	Interrupt clear 1
09H	INTCL2	W	---	---	CLCOU2	CLCOU1	CLTRQ2U	CLTRQ1U	CL1U	CLDCU	-		RSTB	Interrupt clear 2
0AH	INTCL3	W	CLBKMODE	CLBKUP	CLSDSTA	CLSDOSC	CLBATBK	CLREF	CLWRTMP	CLDCOC	-		RSTB	Interrupt clear 3
0BH	INTCL4	W	---	---	---	CLPEXCNT2	CLPEXCNT1	CLPSUSP	CLPBKCNT	CLPRSTB	-		RSTB	Interrupt clear 4
0CH	INTMSK1	R/W	MSKTRQ2OC	MSKTRQ1OC	MSKBSOC	---	MSKTRQ2L	MSKTRQ1L	MSK1L	MSKDCL	00H	O	RSTB	Interrupt mask 1
0DH	INTMSK2	R/W	---	---	MSKCOU2	MSKCOU1	MSKTRQ2U	MSKTRQ1U	MSK1U	MSKDCU	00H	O	RSTB	Interrupt mask 2
0EH	INTMSK3	R/W	---	---	MSKSDSTA	MSKSDOSC	---	MSKREF	MSKWRTMP	MSKDCOC	00H	O	RSTB	Interrupt mask 3
0FH	INTMSK4	R/W	---	---	---	MSKPEXCNT2	MSKPEXCNT1	MSKPSUSP	MSKPBKCNT	MSKPRSTB	00H	O	RSTB	Interrupt mask 4
10H	CONF	R/W	---	---	---	RSTMD	---	RSTERR	SPIWDT	ADVWD	00H	O	DET0O	Configuration register
11H	PRTCT	R/W	RDMKEY<7:0>								**H		RSTB	Protect remove code
12H	RSTFAC	R	---	STPERR	OVADV	LVCORE	TSDTMP	WDEXP	WDSUS	LVLDO1	00H		DET0O	Reset factor
13H	RSTFCL	W	---	CLSTPERR	CLOVADV	CLLVCORE	CLTSDTMP	CLWDEXP	CLWDSUS	CLLVLDO1	-		RSTB	Reset factor clear
14H	RSTFMSK	R/W	---	---	MSKOVADV	---	MSKTSDTMP	MSKWDEXP	MSKWDSUS	---	00H	O	RSTB	Reset factor mask
15H	PINSET	R/W	---	---	DEXCNT2<1:0>		---	---	SELDT	ERMODE	00H		RSTB	EXCNT and error monitor setting
16H	WDTRG	R/W	OPE<1:0>		SUBJ<5:0>						**H		RSTB	WD advanced mode
17H	WDTIME	R/W	---	---	---	---	CWSET<1:0>		WDTIME<1:0>		01H	O	RSTB	WD window time setting
18H	MUXCNT	R/W	---	MUXCNT	---	---	MUXSEL<3:0>				00H		RSTB	Muxamp control
19H	QAEVA	R	ACCVA<7:0>								00H		RSTB	Accumulated value for WD advanced mode
1AH	TRQCNT	R/W	---	---	---	TRQLVSEL	---	---	VTRQ2CNT	VTRQ1CNT	00H	O	RSTB	TRACK1/2 on/off control
1BH	DCLIM	R/W	---	---	---	---	INTIME<1:0>		DTIME<1:0>		04H	O	DET0O	Limit control for DCDC
1CH	RSTVA	R/W	SETVA<7:0>								FFH		RSTB	Number of reset for WD advanced mode
1DH	SFTRST	W	RDMKEY<7:0>								-	O	RSTB	Software reset
1EH	SENTMP	R/W	WARREL<1:0>		THREL<1:0>		WARDET<1:0>		---	---	94H	O	DET0O	Thermal shutdown temperature
1FH	BSSET	R/W	INTIMEBS<1:0>		DTIMEBS<1:0>		---	---	---	BSCNT	41H	O	RSTB	BOOST DCDC control

Note: The initial value of PRTCT, WDTRG are undefined value.

4.2.6. Electrical characteristics

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
SPICLK delay	tdck	From SPICSB↓	400	-	-	ns
SPICLK period	tcyc		800	-	-	ns
H period of SPICLK	thigh		320	-	-	ns
L period of SPICLK	tlow		320	-	-	ns
Command set-up	tcmsu	From last SPICLK ↑	400	-	-	ns
Data set-up	tsu	Before SPICLK ↑	100	-	-	ns
Data hold	thd	After SPICLK ↑	100	-	-	ns
Data access time	tacc	From SPICLK ↓	-	-	50	ns
Read data Hi-Z time	thiz		-	-	50	ns
Data active delay	tact	After SPICSB ↓	-	-	50	ns
H width of SPICSB	twidth		2800	-	-	ns

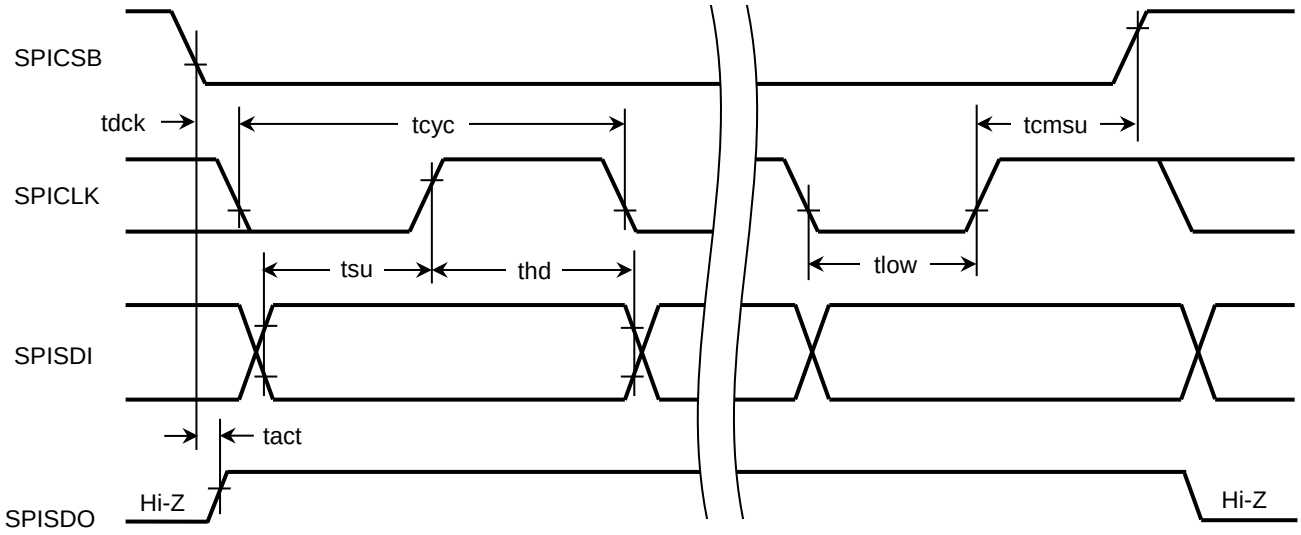


Figure 4-5 SPI write timing

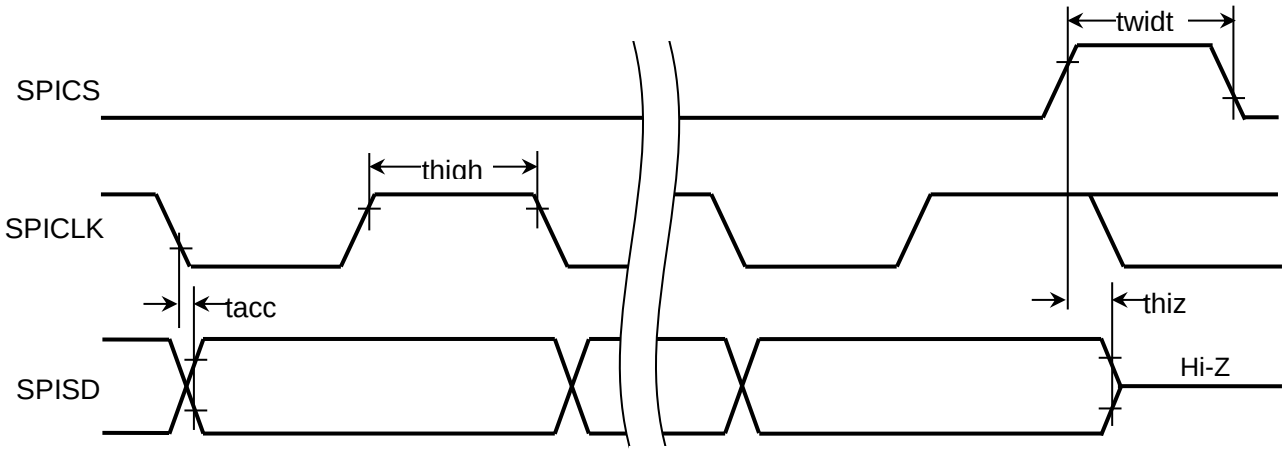


Figure 4-6 SPI read timing

4.3. Reference Voltage

Below figure shows simplified reference voltage generator block.

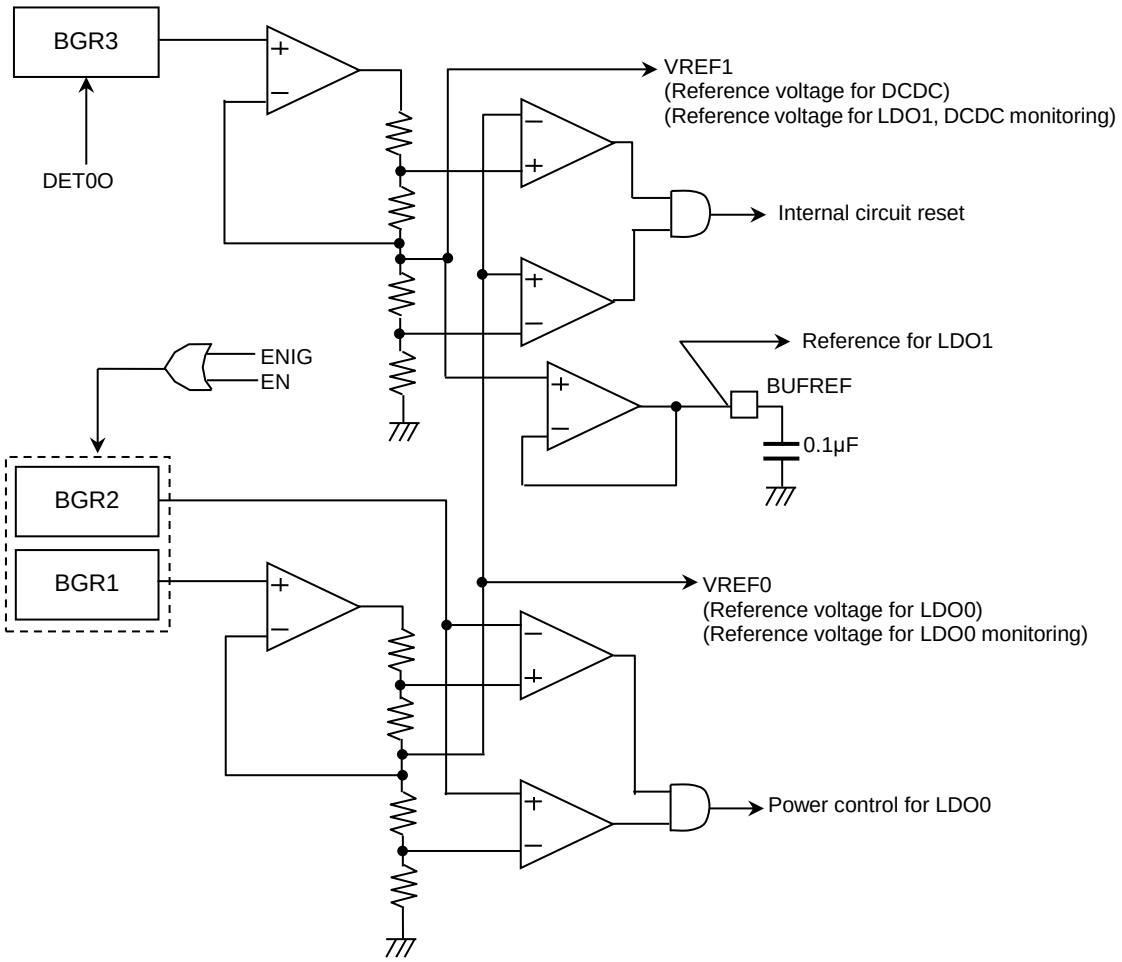


Figure 4-7 REF block diagram

There are three Band Gap Reference (BGR) circuits in the PMIC. In Figure 4-7, if BGR1 or BGR2 has damage, the PMIC does not power up. If BGR3 suffers damage, LDO0 powers up and Buck DCDC and LDO1 does not power up.
BUFREF is the reference voltage for LDO1. In order to apply “clear” supply for ADC in MCU, 0.1µF capacitor is recommended to connect to ground.

4.3.1. Electrical characteristics

Co=0.1µF (ESR=0~0.1Ω)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
BUFREF output voltage	VBUF	BUREF	1.176	1.200	1.224	V

4.4. LDO

The PMIC includes two LDOs. Each LDO requires a ceramic capacitor on its output. The gain stage of LDO1 is operated with 3.3V generated by LDO0. And LDO1 input of power stage has to be connected to the buck DCDC's output. These LDOs have a protection circuit with fold back characteristics (Refer to section 4.4.1).

◆ LDO0

The LDO0 output should be used as power supply for internal circuit of the PMIC. The typical output voltage is 3.3V. The LDO0 output contains an output voltage detector.
When the over voltage is detected, the power line switch for internal circuit of the PMIC cut off supply power. Or when the low voltage is detected, The PMIC makes reset and initializes internal register. The detect voltages are described in section 4.12.4.

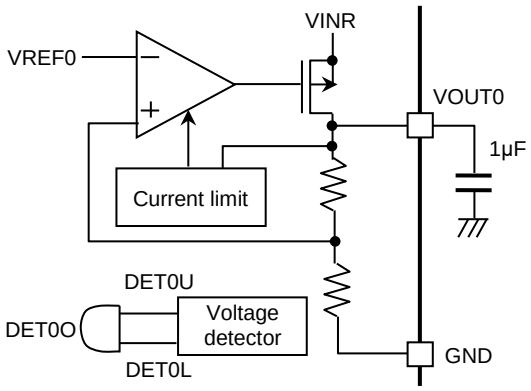


Figure 4-8 LDO0 block diagram

◆ LDO1

The LDO1 output should be used as power supply for MCU. The typical output voltage is 5.0V.
The LDO1 includes an output voltage detector. If the output voltage comes across the over voltage, a flag is set into register and INTOUT asserts low. When DET1L1 is detected, SUSP is asserted as the warning. And when DET1L2 is detected, RSTB is asserted. The detect voltages are described in section 4.12.4.

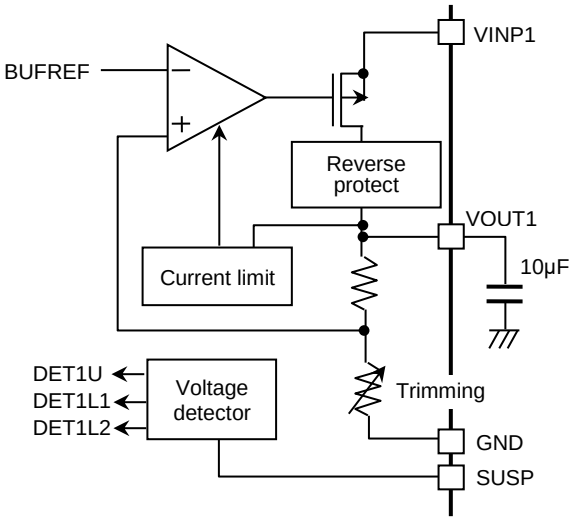


Figure 4-9 LDO1 block diagram

4.4.1. Output protection function

All LDOs have a current limit function. Fold-back characteristic is illustrated in Figure 4-10.
In this figure, “Io” is a guaranteed current which maintains the specified output voltage. For more than “Io” current, the more output current flows, the lower output voltage goes down with decreasing output current

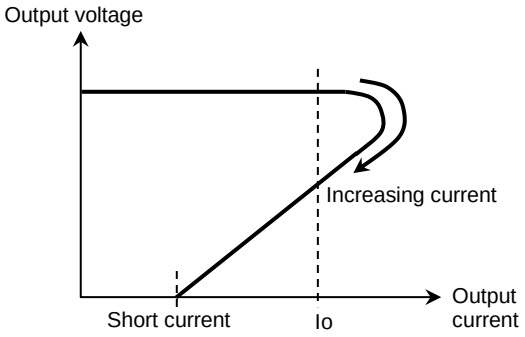


Figure 4-10 Fold-back characteristic

4.4.2. Electrical characteristics

Characteristics noted under conditions GND=0V, unless otherwise noted. The TYP condition is Ta=25°C.

◆ **LDO0**

C0=1.0µF (ESR=0~0.1Ω)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Output voltage	Vo0	Io=0~10mA (DC)	3.20	3.30	3.40	V
Short current	Is0	Vo=0V	-	-	20	mA

Note: “(DC)” means not to include AC factor like transient response.

◆ **LDO1**

C1=10µF (ESR=0~0.1Ω), VDC~VINP1 connected

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Output voltage	Vo11	VINPDC>5.75V, Io=0~350mA (DC)	4.90	5.00	5.10	V
	Vo12 *	VINPDC=5.4V, Io=300mA (DC)	4.75	-	-	V
	Vo13 *	VINPDC=3.8V, Io=300mA (DC)	3.20	-	-	V
Short current	Is1	Vo=0V	-	-	100	mA

Note: “(DC)” means not to include AC factor like transient response.
*: Guaranteed by Design Engineering

4.5. Tracker

The PMIC includes two trackers. Each tracker needs a ceramic capacitor on its output. The buffer on the tracker is operated by 3.3V generated at the LDO0. And each input of power stage has to be connected to buck DCDC's output. Set VTRQ1CNT1 or VTRQ2CNT to 1 to activate the trackers.

◆ **TRACK1**

TRACK1 is an auxiliary power rail. This output voltage follows to VOUT1. The power up control is set via SPI. This tracker has high voltage protect function to prevent reverse current from the output. When the output touch high voltage like battery, this circuit stops reverse current toward the PMIC. TRACK1 has a voltage/current detector which assert INTOUT to low, if the over/low voltage or over current is detected. The detect voltages are described in section 4.12.4.

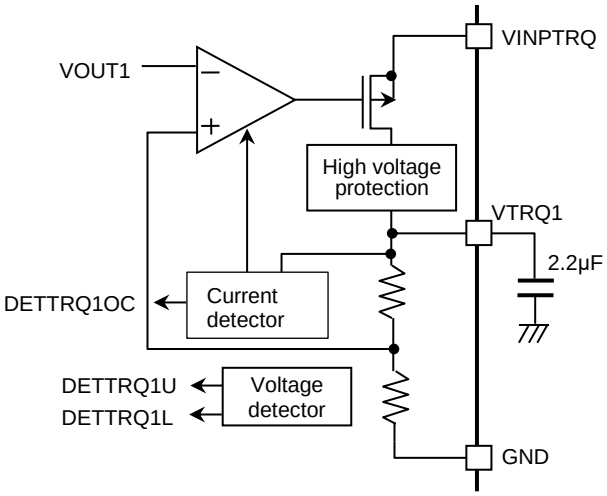


Figure 4-11 TRACK1 block diagram

◆ **TRACK2**

TRACK2 is an auxiliary power rail. This output voltage follows to VOUT1. The power up control is set via SPI. This tracker has high voltage protect function to prevent reverse current from the output. When the output touch high voltage like battery, this circuit stops reverse current toward the PMIC. TRACK2 has a voltage/current detector which assert INTOUT to low, if the over/low voltage or over current is detected. The detect voltages are described in section 4.12.4.

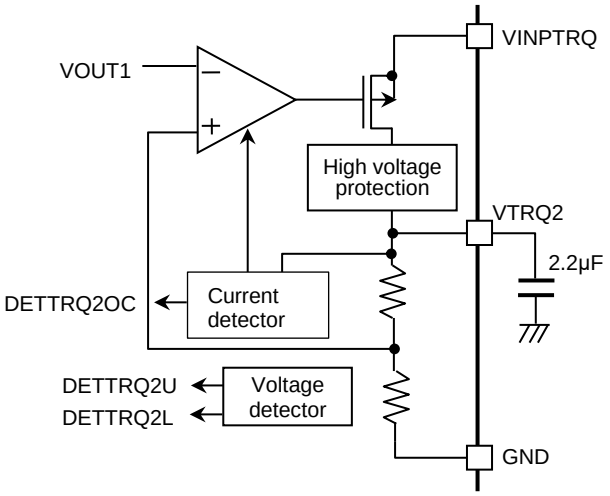


Figure 4-12 TRACK2 block diagram

Caution:
If over current or low voltage is detected, the tracker is suspended for the protection. The VTRQ1CNT or VTRQ2CNT register set 0 once, and then set 1 to reboot the tracker.
Not allow to add over 20µF in addition to 2.2µF in Figure 4-11 and Figure 4-12.

4.5.1. Register

The content of TRACK1/2 setting controls output and changes low voltage detection.

- TRACK1/2 setting
  The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

  - Address (TRQCNT): 1AH

A5	A4	A3	A2	A1	A0
0	1	1	0	1	0

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	TRQLVSEL	-	-	VTRQ2CNT	VTRQ1CNT

  - Setting contents

Register name		Control contents	Setting	
			1	0
TRQLVSEL	D4	Low voltage detection on TRACK1/2	92.5%	48.6% *
VTRQ2CNT	D1	TRACK2 On/Off	On	Off *
VTRQ1CNT	D0	TRACK1 On/Off	On	Off *

* Default setting

Note: Set TRQLSEL before start-up. TRQLVSEL changes both TRACK1 and TRACK2 low voltage detection.

4.5.2. Electrical characteristics

Characteristics noted under conditions GND=0V, unless otherwise noted. The TYP condition is Ta=25°C.

◆ **TRACK1**

CTRQ1=2.2µF (ESR=0~0.1Ω)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Matching output error	dVTR1	VTRQ1-VOUT1	-20	-	20	mV
Output current	Iotr11		100	-	-	mA
Power on time	Trtrq1 *	90% output	-	1.8	2.4	ms

*: Guaranteed by Design Engineering

◆ **TRACK2**

CTRQ2=2.2µF (ESR=0~0.1Ω)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Matching output error	dVTR2	VTRQ2-VOUT1	-10	-	10	mV
Output current	Iotr2		100	-	-	mA
Power on time	Trtrq2 *	90% output	-	1.8	2.4	ms

*: Guaranteed by Design Engineering

4.6. DCDC converter (DCDC)

The PMIC includes two types of DCDCs: buck and boost. The internal high-side PMOS power stage is implemented in the buck DCDC. The buck DCDC requires some external device in Figure 4-13. The boost DCDC operates down to 2.2V battery voltage (VBAT) by configuration in Figure 4-16 and that output connects to the input of the buck DCDC. The buck DCDC has output monitoring which protect the DCDC output and the over-current by a detector monitoring the over and low voltage.

4.6.1. Buck DCDC

The buck DCDC operates with current mode control and is supposed to supply power as intermediate power supply. LDO1 and trackers input should be connected to the buck DCDC's output. The buck DCDC includes an output voltage detector. If the output voltage comes across over or low voltage, the flag is set into register and INTOUT signal is occurred. The detect voltage is described in section 4.12.4.

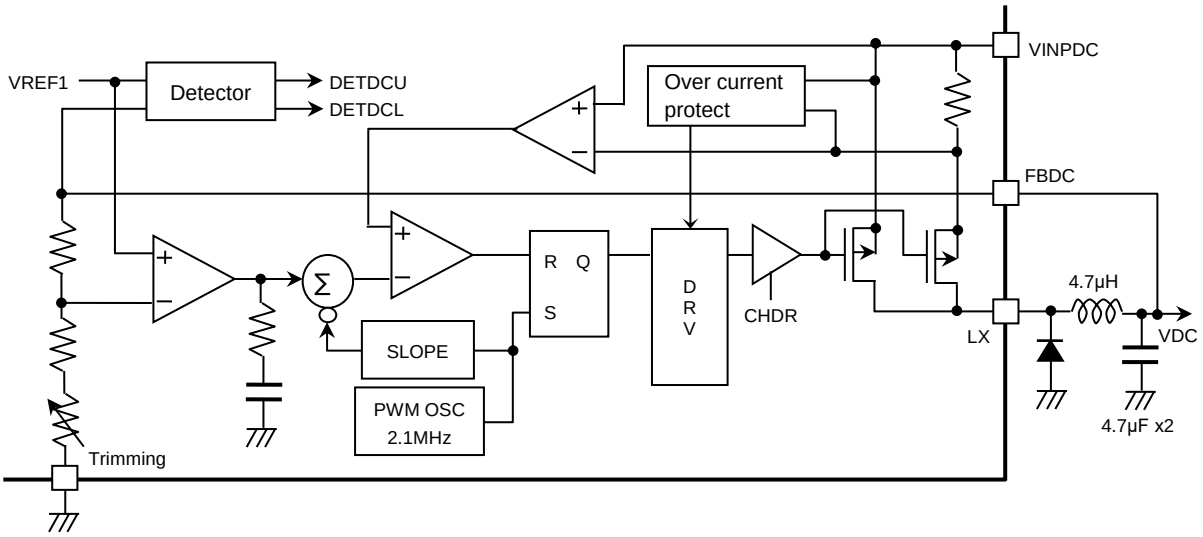


Figure 4-13 Buck DCDC block diagram

◆ **Buck DCDC output protect function**

The buck DCDC monitors the output current and output voltage. In the case that over voltage is detected on the buck DCDC, the PMIC stops the buck DCDC's switching. When over current or low voltage are detected with taking over detection time, then the buck DCDC enters the interval operation. The detection time of over current and the interval time of resuming can be set via SPI.

Before the buck DCDC's operation comes into the protect mode, INTOUT is asserted low. The operation timing is shown in Figure 4-14 and Figure 4-15.

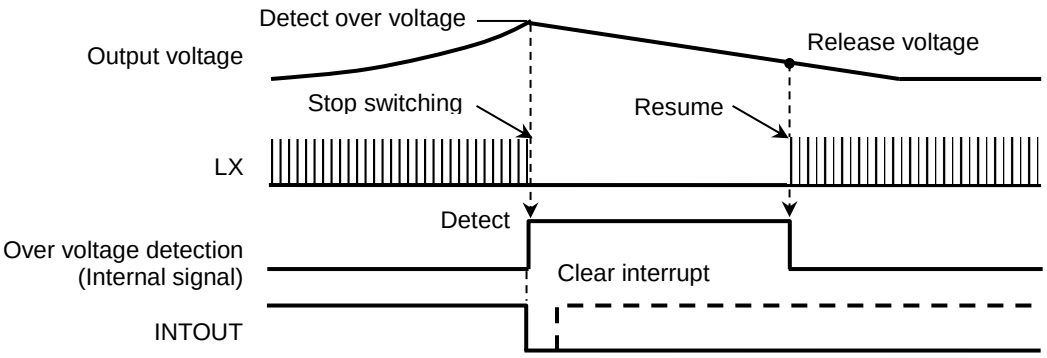


Figure 4-14 Buck DCDC protect function behavior 1

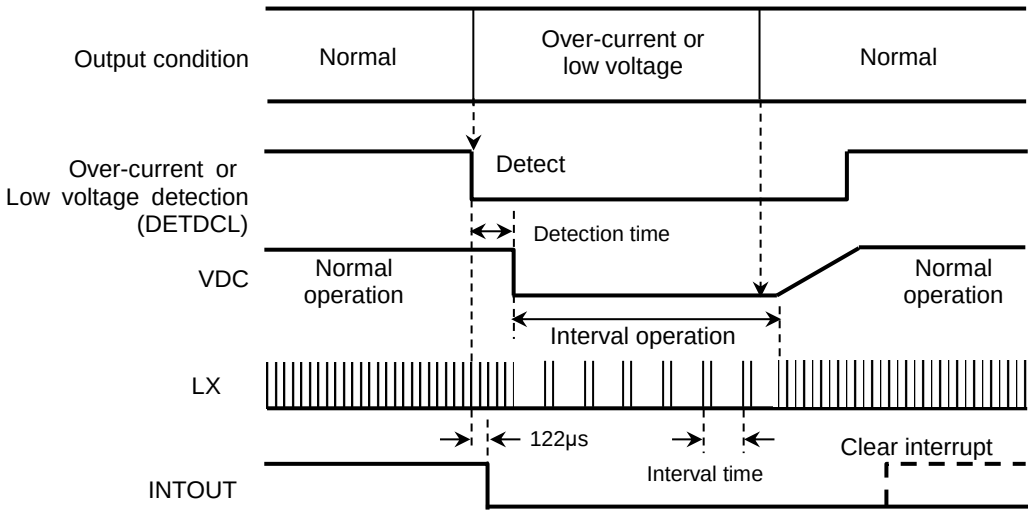


Figure 4-15 Buck DCDC protect function behavior 2

4.6.2. Boost DCDC

The PMIC operates without a reset signal until the input voltage (VBAT) is down to Vdbu. The boost DCDC should be operated in the lower VBAT voltage to maintain the PMIC function. Some external devices shown in Figure 4-16 is required for the boost operation. The output of the boost DCDC (VBS) is connected to the input of the buck DCDC (VINPDC) or LDO0 (VINR) and BSCNT is set to 1. the boost DCDC is activated when the VBAT is lower after starting up the PMIC.

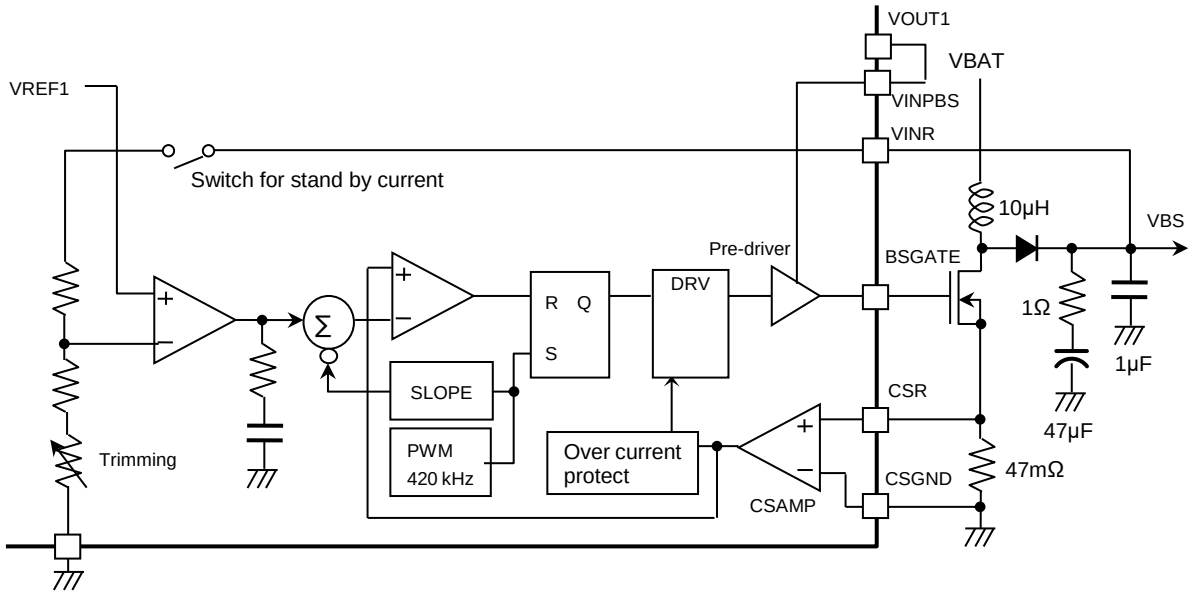


Figure 4-16 Boost DCDC block diagram

The timing chart in the boost operation is shown in Figure 4-17.
The VBAT is same voltage to the VINR in the normal. The boost DCDC is enabled when the VINR voltage is lower than VoDC2. The VBAT returns to the normal, then the boost DCDC is suspended.

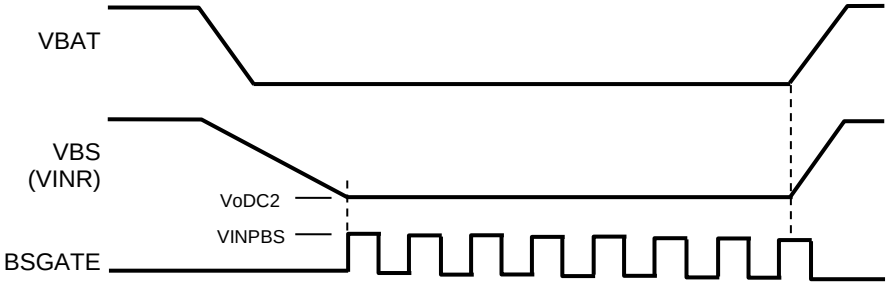


Figure 4-17 Timing chart (boost DCDC)

◆ **Boost DCDC output protect function**

The boost DCDC stops the switching when over current is detected though a resister both CSR and CSGND, moves the interval operation. The PMIC goes to the power down state and stops the buck DCDC and LDO1 if VBS(VINR) is under Vdbu after over current detecting.
The detection time of over current and the interval time of resuming can be set via SPI.
Before the boost DCDC's operation comes into the protect mode, INTOUT is asserted low. The operation timing is shown in Figure 4-18.

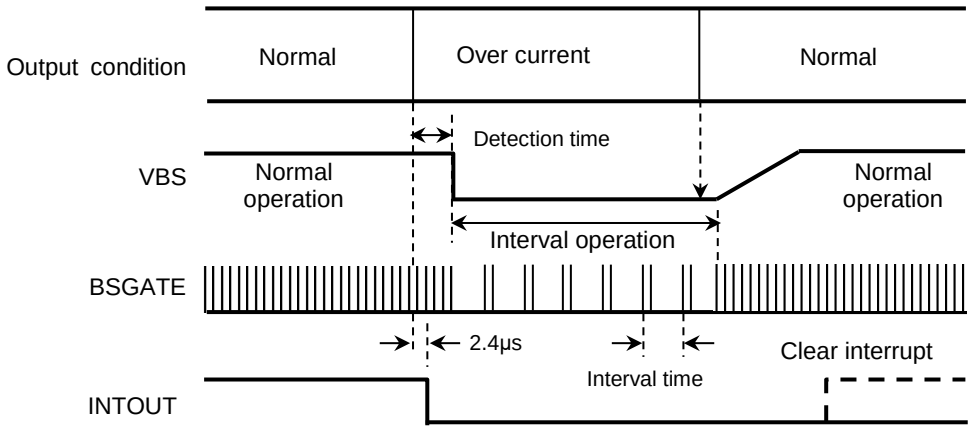


Figure 4-18 boost DCDC protect function behavior

4.6.3. Register

The contents of protect function setting are described here.

- Buck DCDC protection mode setting

  The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

  - Address(DCLIM): 1BH

A5	A4	A3	A2	A1	A0
0	1	1	0	1	1

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	-	INTIME (1:0)		DTIME (1:0)	

  - Setting contents

  Interval time and over current detection time for the buck DCDC

INTIME (1:0)		Interval time
D3	D2	
0	0	15.6ms
0	1	31.2ms *
1	0	124.9ms
1	1	249.9ms

* Default setting

DTIME (1:0)		Detection time
D1	D0	
0	0	122µs *
0	1	122µs
1	0	610µs
1	1	1098µs

* Default setting

Note: INTOUT is low in 122µs regardless of DTIME.

- Boost DCDC protection mode setting

  The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

  - Address(BSSET): 1FH

A5	A4	A3	A2	A1	A0
0	1	1	1	1	1

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
INTIMEBS (1:0)		DTIMEBS (1:0)		-	-	-	BSCNT

  - Setting contents

  Interval time and over current detection time for the boost DCDC

INTIMEBS (1:0)		Interval time
D7	D6	
0	0	4.8µs
0	1	11.9µs *
1	0	312.1ms
1	1	624.2ms

* Default setting

DTIMEBS (1:0)		Detection time
D5	D4	
0	0	2.4µs *
0	1	2.4µs
1	0	11.9µs
1	1	2440µs

* Default setting

Register name		Control contents	Setting	
			1	0
BSCNT	D0	Boost DCDC enable	Enable *	Disable

* Default setting

Note: INTOUT is low in 2.4µs regardless of DTIMEBS.

4.6.4. Electrical characteristics

Characteristics noted under conditions GND=0V, unless otherwise noted. The TYP condition is Ta=25°C.

◆ **Buck DCDC**

Co=4.7µF x2 (ESR=0.0~0.1Ω), L=4.7µH

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Output voltage	VoDC1	Io=0~600mA (DC)	5.90	6.10	6.30	V
OSC frequency	Fosc1		1890	2100	2310	kHz

Note: “(DC)” means not to include AC factor like transient response.

◆ **Boost DCDC**

Co=47µF (electrolytic capacitor, ESR=0.01~6Ω) + 1.0µF (ESR=0.0~0.1Ω), L=10µH

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Output voltage	VoDC2	VBAT=2.2V, Io=0~250mA(DC)	5.70	6.00	6.40	V
OSC frequency	Fosc2		378	420	462	kHz

Note: “(DC)” means not to include AC factor like transient response.

4.7. Power Rail Sequence

When the battery voltage is applied to the PMIC, the LDO0 rises up first. After the LDO0 rises up, the buck DCDC and LDO1 are powered up in the sequence automatically. After LDO1 rises up, reset signal is released.

4.7.1. Power up sequence

After the PMIC is applied supply voltage, the buck DCDC(VDC) and VOUT1 rise up automatically. If a back-up supply is connected, the PMIC powers up the back-up supply once to detect it after self-diagnosis. The rise up timing of VOUT1, INTOUT and RSTB are suitable for RENESAS RH850/P1x.

◆ **Power up with ENIG**

While the supply voltage is applied, the PMIC can be controlled by ENIG pin. After ENIG is entered, the self-diagnosis is executed. The buck DCDC and LDO1 are controlled by the internal sequencer. After VOUT1 rises up, the interrupt signal is released. Further 14.5ms passes, the reset signal is released as well. INTOUT is asserted high even if a core voltage (VCL) in MCU is not activated. The PMIC keep the operation by asserted EN high from MCU, if ENIG is low.

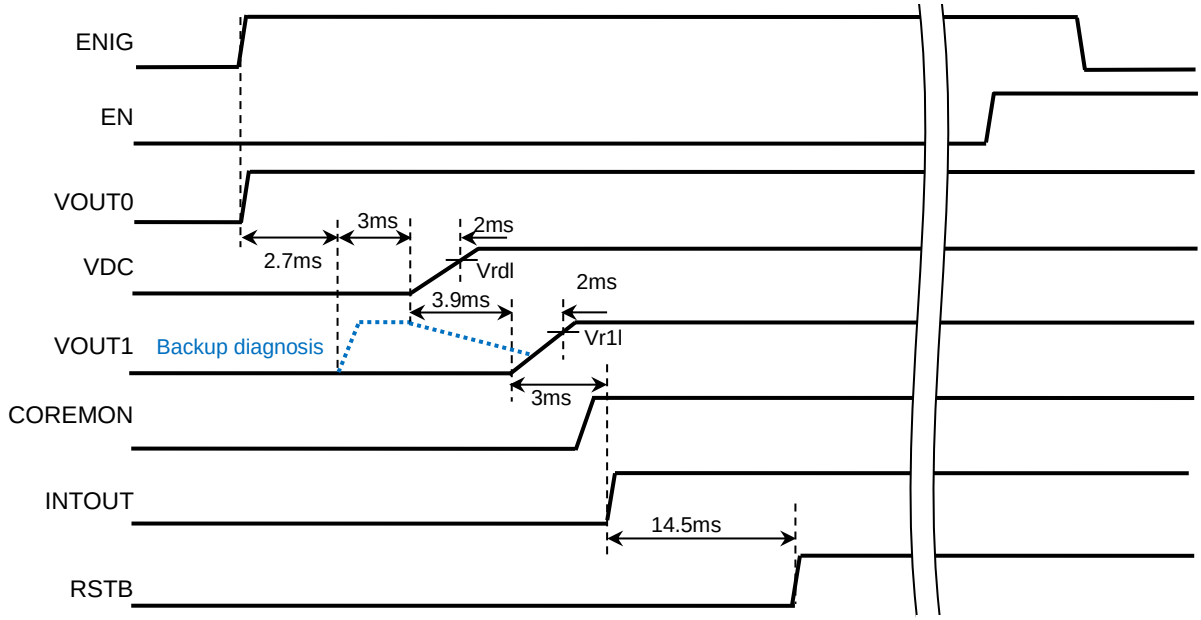


Figure 4-19 Power up timing (with ENIG setting)

◆ **Power up without ENIG**

When ENIG are connected to the supply voltage and the supply voltage comes up, the power up sequence starts automatically. The power up sequence behavior is same as using ENIG. INTOUT is asserted high even if a core voltage (VCL) in MCU is not activated.

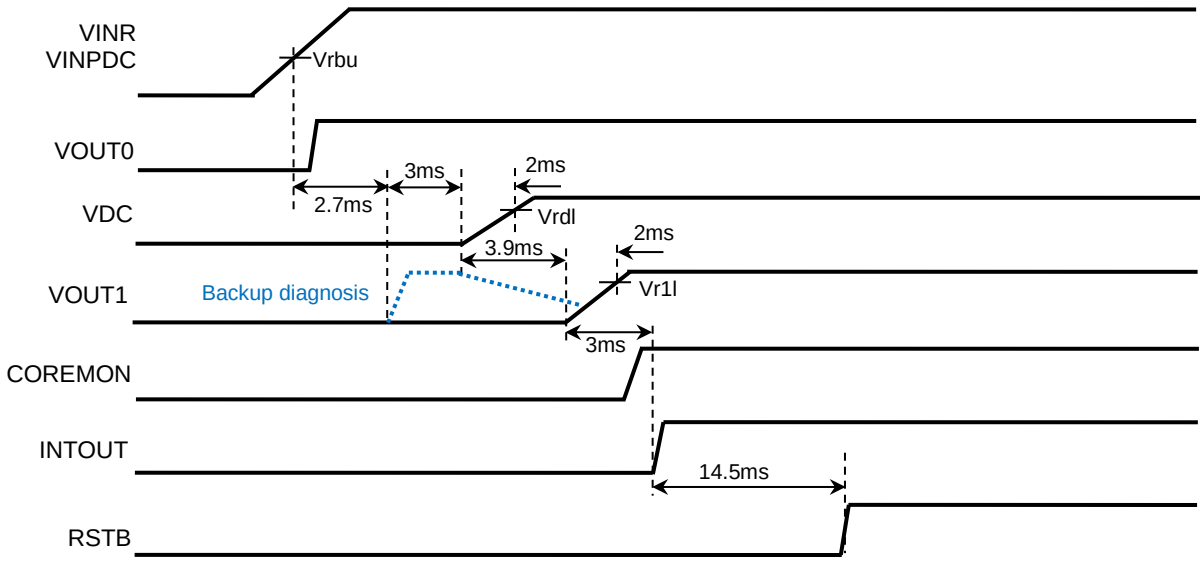


Figure 4-20 Power up timing (Supply power coming up)

4.7.2. Power down sequence

When the PMIC powers down, all regulators fall down automatically. The difference of fall down time between each regulator is suitable for RENESAS RH850/P1x.
The PMIC is not re-activated without the low voltage detection (Vd1l2) in the LDO1 after the power down sequence.

◆ **Power down with ENIG**

When the PMIC is stopped operating by ENIG, the power down sequence is started by asserted ENIG and EN low. After INTOUT and RSTB is low, the LDO1 or the buck DCDC is powered down. The LDO0 is powered down after VOUT1 detects Vd1l2.

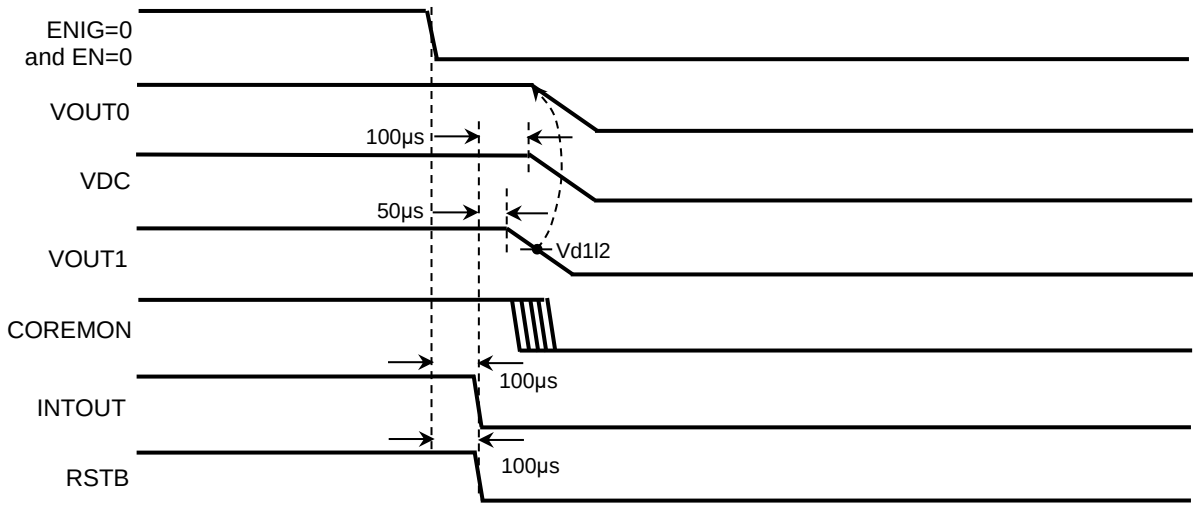


Figure 4-21 Power down timing (with ENIG/EN setting)

◆ **Power down without ENIG, EN**

The output behavior in low supply voltage is shown in the below figure. Even though the supply voltage of the PMIC goes down lower than the output voltage of the buck DCDC, regulators can generate the output voltage. But the output voltage becomes to be almost same as the supply voltage.
When the supply voltage falls down and VOUT1 goes across Vd1l1, the PMIC asserts that INTOUT is low. Further the supply voltage goes across Vdbu or VOUT1 goes across Vd1l2, the PMIC asserts that RSTB is low.

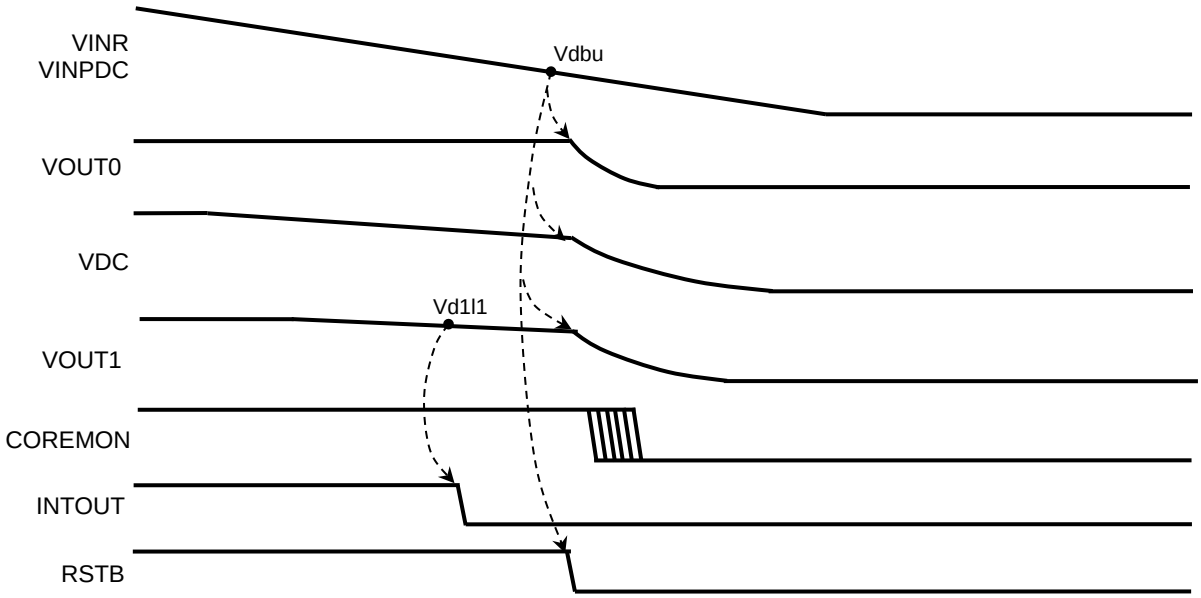


Figure 4-22 Power down timing (Supply voltage falling down)

◆ **Power down by low voltage of VOUT1**

When VOUT1 goes across Vd1l2, the PMIC asserts that RSTB is low and moves to the power down sequence. The PMIC turns off the LDO1 and the buck DCDC.

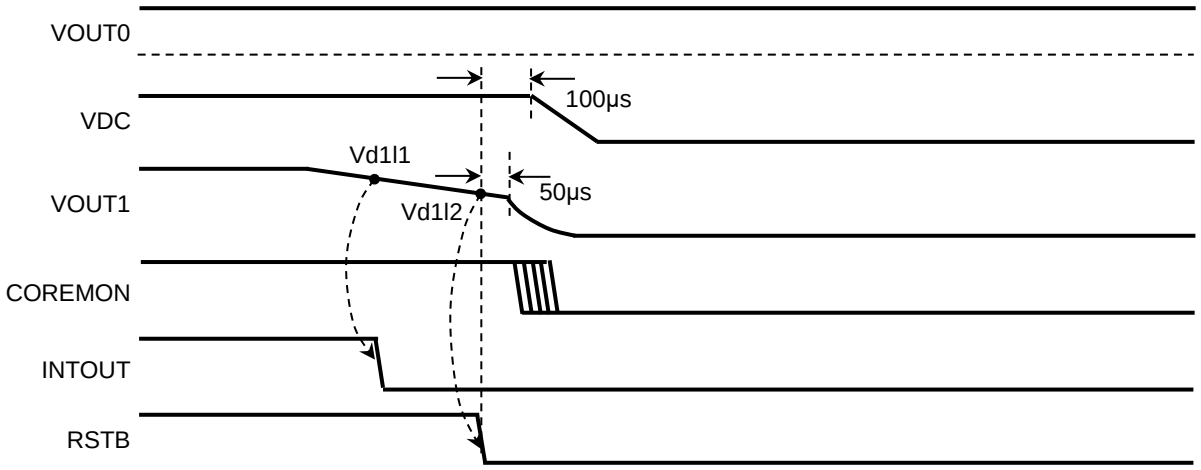


Figure 4-23 Power down timing (VOUT1 low voltage detection)

4.7.3. Working with a backup-power

If the buck DCDC or LDO1 is in unusual operation, the backup is powered up.

◆ **Buck DCDC unusual operation**

When the buck DCDC detects over, low voltage or over current, the backup-power is risen up instead of the LDO1 if the PMIC is connected with the backup-power. If no back up, the LDO1 is risen up. Even DCDC goes back to the normal operation, the backup-power is operated until the operation mode is the stand-by.

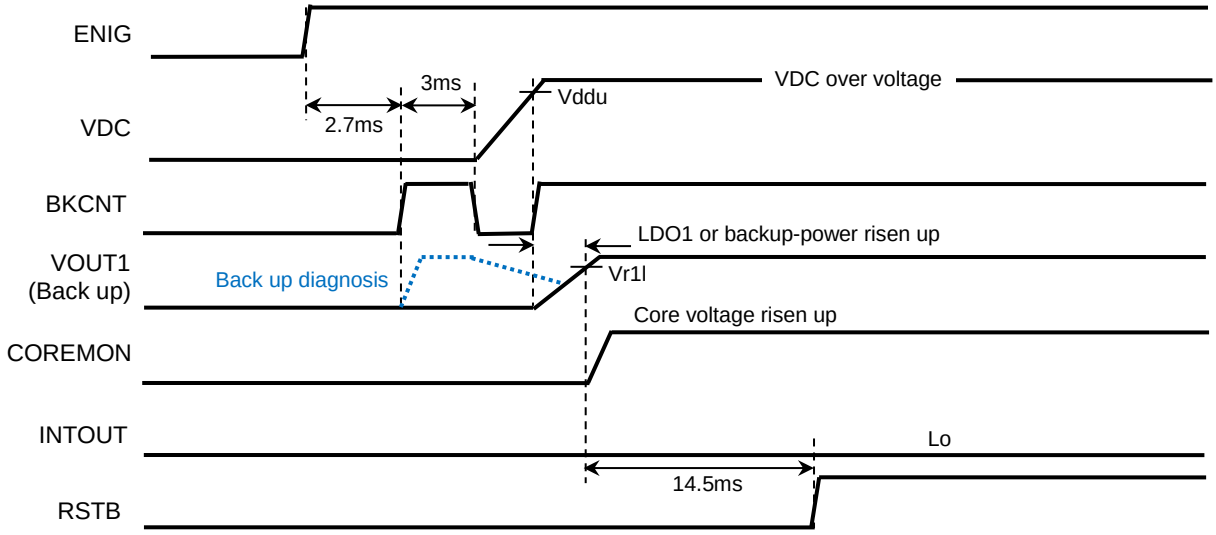


Figure 4-24 Power up timing (Backup-power)1

◆ **LDO1 low voltage**

If the low voltage is detected on LDO1 during the PMIC starting up, the backup-power is risen up and LDO1 is suspended. The backup-power is operated until the operation mode is the stand-by.

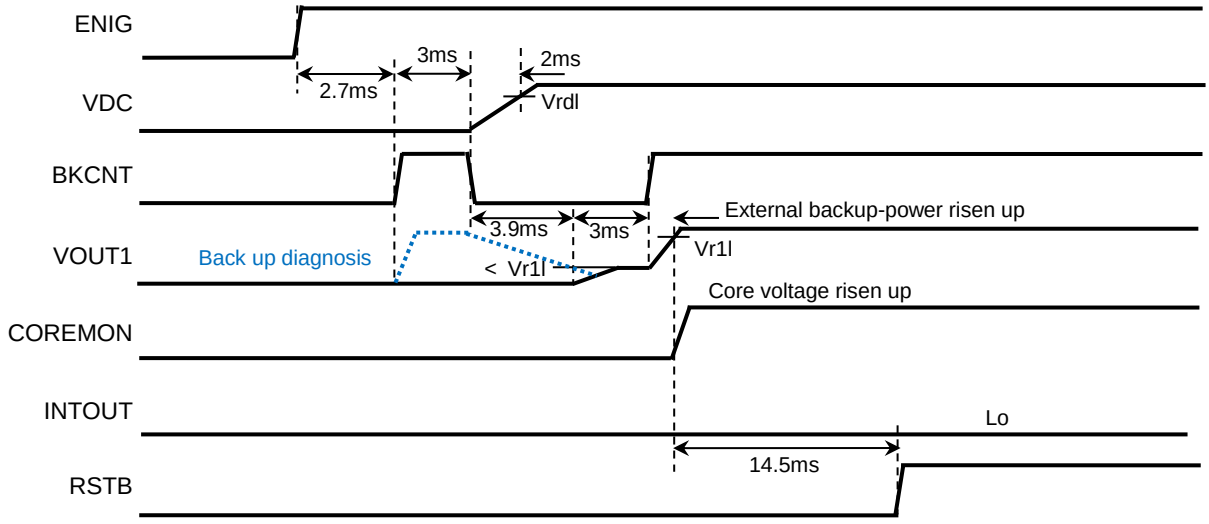


Figure 4-25 Power up timing (Backup-power)2

◆ **Backup-power power down**

The backup-power executes power down sequence.

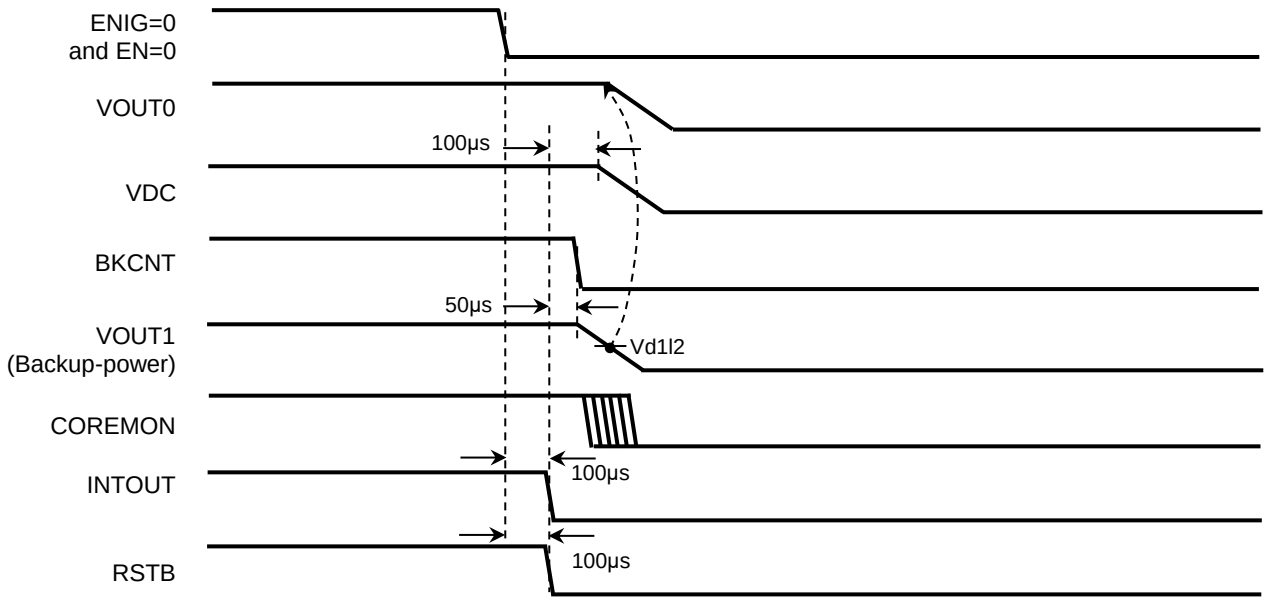


Figure 4-26 Power down timing (Back up suppy)

4.8. Watchdog Timer (WDT)

The watchdog (WD) timer can be used for monitoring the system health to prevent a runaway operation. In order to refresh WD timer (WDT), a trigger via SPI or on WDI pin is required.

4.8.1. Window WDT

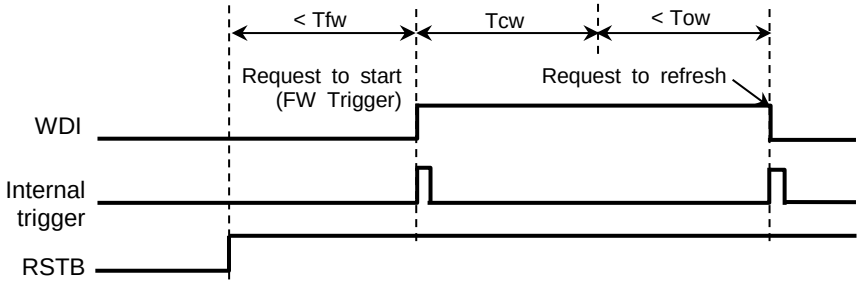
The window WDT is implemented in the PMIC. A trigger is required to start the WD operation during first window (FW) in “Normal” state. If the trigger is not executed, a reset pulse is occurred and the PMIC waits for a FW trigger again. After WD starts operating in “System monitor” state, a trigger should not be executed during Close Window (CW). A trigger should be executed to refresh the timer during Open window (OW). If the refreshing is not executed within designated time in OW, a reset pulse occurs. While the WDT is operating and when SUSP is asserted, the WDT stops its operating. And when SUSP is released, then the WDT resumes FW in “Normal” state.
The CW time and the OW time are programmed via SPI.

4.8.2. WDT operation

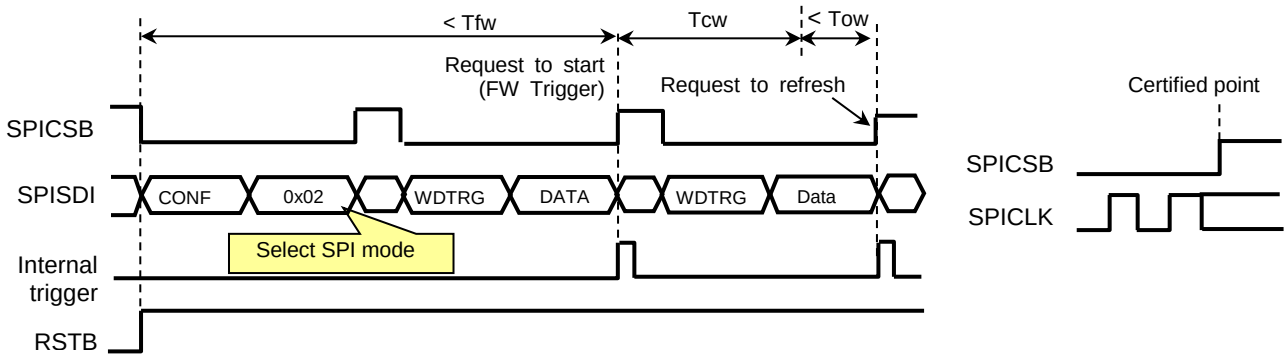
The detail WD operation is described in this section. In order to clear the timer, toggling on WDI or SPI is required.

◆ Operation in normal

The below figure shows the normal operation of WDT when the trigger from WDI pin or SPI is entered within designated time. The certified point as a trigger is the both edge of WDI or rising edge of SPICSB. In SPI mode, the parity bit should be set to the correct data to be checked by the PMIC even though any data can be written into WD trigger address(WDTRG).



(a) WDT timing in WDI mode



(b) WDT timing in SPI mode

Figure 4-27 WDT normal operation

◆ Behaviors in unusual operation

A reset is occurred when the trigger in CW or when the OW timer expires.

(1) No trigger in FW

When the trigger is not entered in FW, a reset is occurred. After that, if no triggers are entered, a reset is occurred frequently on the periodic interval. If RSTMD register is set to 1, RSTB maintains low (the reset is low after the PMIC's restart through stand-by state in the PMIC.).

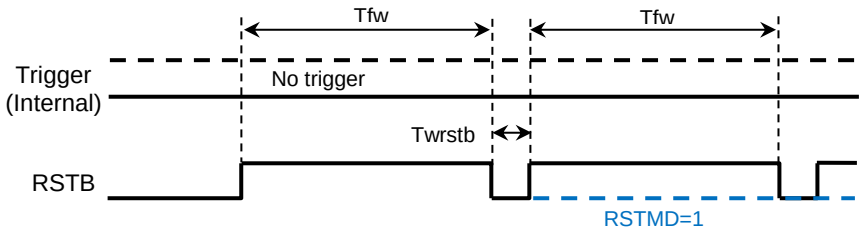


Figure 4-28 No trigger in FW

(2) A trigger in CW

When the trigger is entered in CW, a reset is occurred. RSTMD is set to 0, INTOUT asserts low. WDSUS in the reset factor register is set to 1. RSTMD is set to 1, RSTB maintains low (the reset is low after the PMIC's restart through stand-by state in the PMIC.).

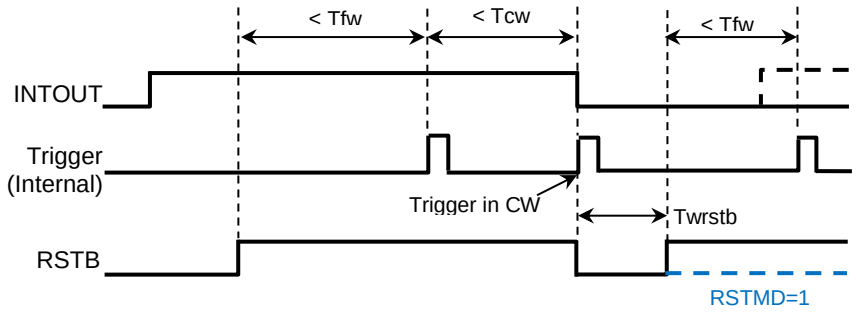


Figure 4-29 Trigger in CW

(3) No trigger in OW

When the trigger is not entered in OW, the timer is expired and a reset is asserted. RSTMD is set 0, WD is restarted from FW after the reset is released. INTOUT asserts low. WDEXP in the reset factor register is set to 1. RSTMD is set to 1, RSTB maintains low (the reset is low after the PMIC's restart through stand-by state in the PMIC.).

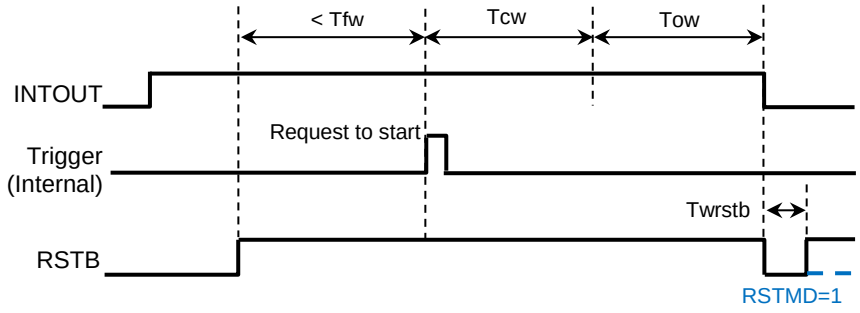


Figure 4-30 No trigger in OW

◆ **WD operation suspend**

When the output voltage on VOUT1 comes down and SUSP asserts low, then WD stops its operation. And SUSP is changed to high, WD resumes the operation form FW.

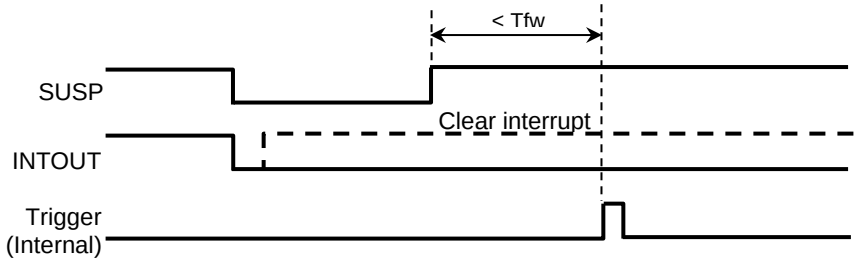


Figure 4-31 WD operation suspend

4.8.3. Advanced mode

Advanced mode WDT is MCU and the PMIC are monitoring each other operation. Set the configuration register (CONF) to “Advanced mode”. The “Advanced mode” is enable in the case of setting to SPI in SPIWDT.

After WD operation starts, MCU should obtain a “Question” to send an “Answer” to the PMIC. (QA monitoring) The “Question” contains operand and objective data. The MCU should send a request to refresh WD timer with data of the “Answer”. The “Answer” is in accordance with the operand in the previous “question”. The PMIC refreshes the WD timer, gives a point for the “Answer”, and accumulates the points to evaluation register. When the accumulated point reaches the designated value, a reset is occurred. The PMIC accepts the other SPI communication form the MCU between “Question” and “Answer”.

If “Advanced mode” is not selected, only refreshing the WD timer is executed. It is possible to change to “Advanced mode” in CW, a reset is occurred if the changing the mode is executed in OW.

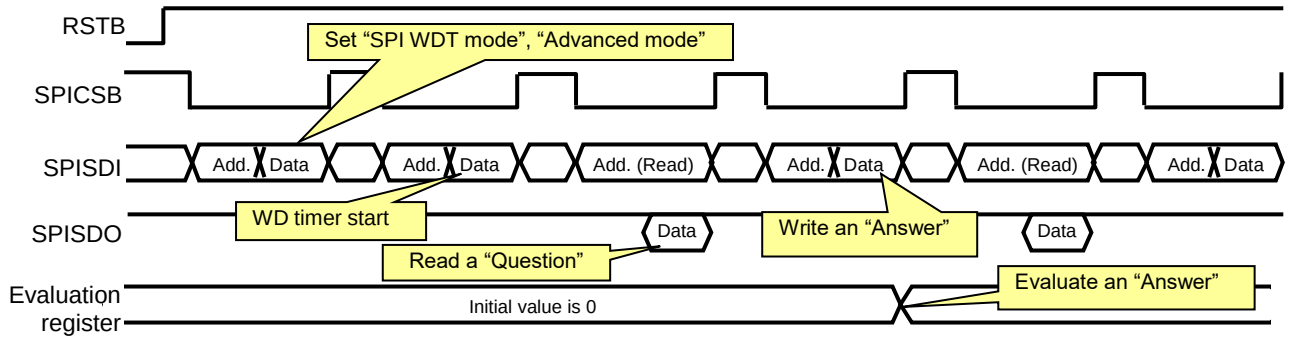


Figure 4-32 QA monitoring operation

◆ **Procedure**

Below figure illustrates the procedure in accordance with Figure 4-32.

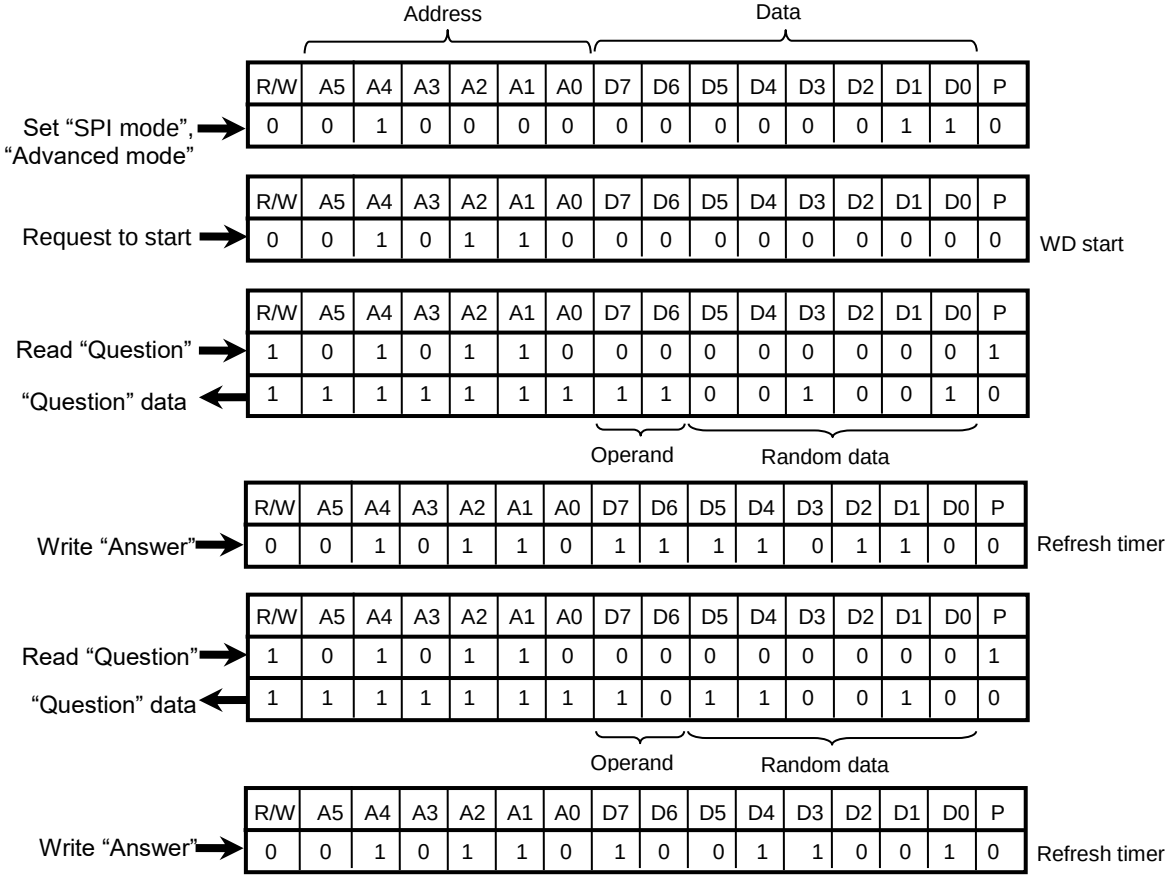


Figure 4-33 Refresh procedure in advanced mode

- Select “SPI mode” and “Advance mode”
  Set the configuration register (CONF) to control WD via SPI and use advance mode.
  In Figure 4-33, D0 bit and D1 bit are set 1.
- Request to WD start
  Enter WD trigger address (WDTRG) to start WD function. The data of WDTRG is ignored in WD start, but the parity bit is checked.
- Read “Question”
  The PMIC generates a random data as a question containing 2bit operand and 6bit objective data. A MCU has to read the question to respond with an answer.
- Write “Answer”
  A MCU enters an answer to the obtained data. The address data to enter an answer is same as a WD trigger address (WDTRG) and refresh the WD timer simultaneously. The data contains 2bit operand and 6bit data operated along with the operand. If the consecutive “Question” reading, the “Question” is the first reading data.

◆ Evaluation register

The PMIC gives a point to the entered answer and has the register (ACCVA) to accumulate the points. The accumulated value is read via SPI. When the WD starts, accumulated point is 0. The evaluation is executed in OW.

- Correct “Answer” sending in OW
  The PMIC gives “-1” point to the evaluation register when a correct answer is entered. If the accumulated value in the evaluation register is 0, the evaluation register is “0”.
  In below example, a correct answer A1 is entered as a response of Q1. And then, “-1” is added to current value of evaluation register.

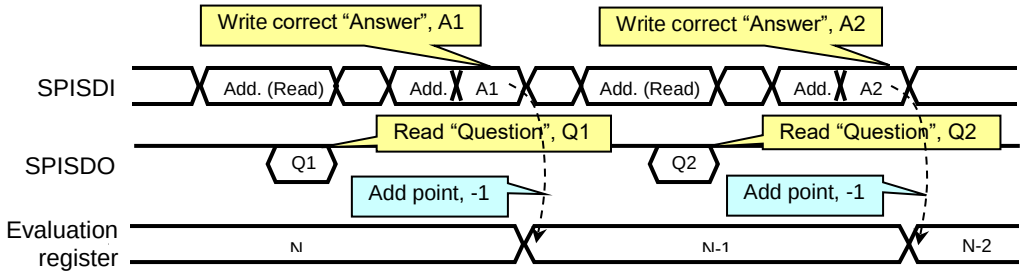


Figure 4-34 Evaluation for enterd answer (Correct answer)

- Incorrect “Answer” sending in OW
  The PMIC gives “+2” point to the evaluation register when an incorrect answer is entered. And the next question is same as previous one.
  In below example, an incorrect answer Ax is entered as a response of Q1. And then, “+2” is added to current value of evaluation register. In spite of incorrect answer, the PMIC refreshes the WD timer.

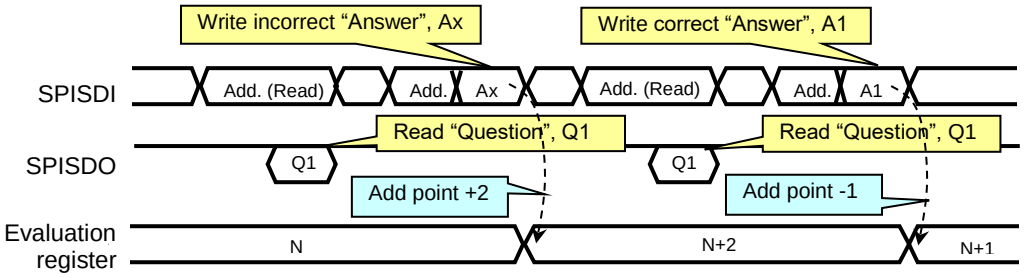


Figure 4-35 Evaluation for enterd answer (Incorrect answer)

- “Answer” bits all “0”
  The PMIC gives “+3” point to evaluation register when the entered bits of the answer are all “0”. The PMIC never create a “Question” which leads the answer’s bits are all 0.

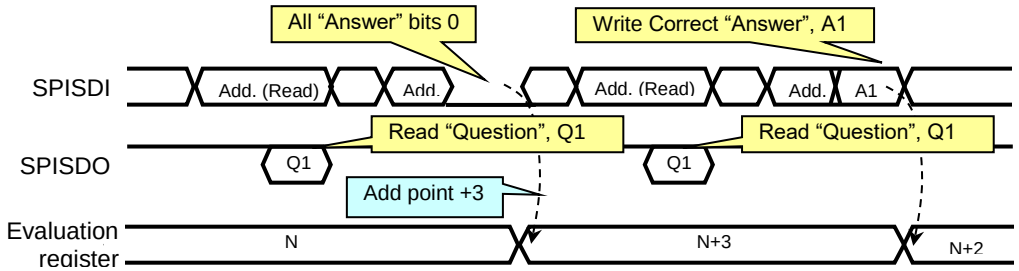


Figure 4-36 Evaluation for enterd answer (No answer)

- Reset by accumulated value
  Through QA monitoring, when accumulated value (ACCVA) is more than designated value (SETVA), a reset is occurred.
  In below example, the reset value of evaluation register (RSTVA) is more than “N+1” and the current value of the evaluation register is “N”. When an incorrect answer is entered, the value comes up to “N+2”. Eventually, the reset is occurred after 4us passes. The pulse width of the reset is 2ms.

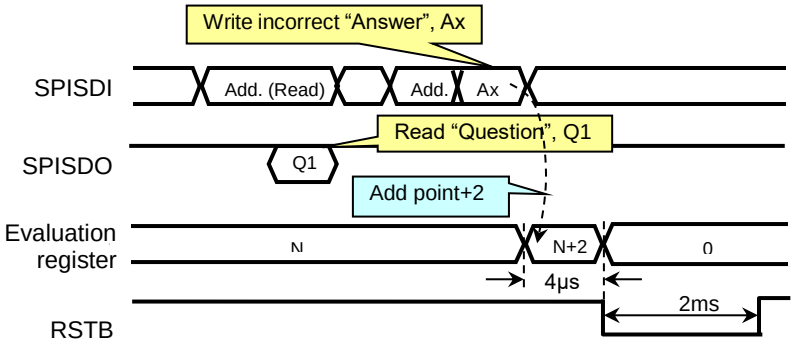


Figure 4-37 Evaluation for enterd answer (In appropriate term)

4.8.4. Register

The contents of WDT setting are described in this section.

- WD trigger
  Only entering address refresh the timer in SPI mode ((D7-D0) data is ignored but the parity bit is checked)

  - Address(WDTRG): 16H

A5	A4	A3	A2	A1	A0
0	1	0	1	1	0

  - Register
    To evaluate “answer”, MCU should enter below data in accordance with the question.

D7	D6	D5	D4	D3	D2	D1	D0
OPE (1:0)		SUBJ (5:0)					

    A MCU should obtain below “question”.

Do7	Do6	Do5	Do4	Do3	Do2	Do1	Do0
OPE (1:0)		SUBJ (5:0)					

■ Setting contents
A MCU should transmit SUBJ calculated the below received D5-D0 bits.

OPE (1:0)		Control contents
Do7	Do6	
0	0	Copy Do5-Do0 bits for D5-D0
0	1	Shift D05-Do0 bits to the 1bit left for D5-D0
1	0	Shift Do5-Do0 bits to the 1bit right for D5-D0
1	1	Invert Do5-Do0 bits for D5-D0

Note: “0” is inserted in the blank Do0 or Do5 after the data shifts right or left

➢ Watch dog time
This register can set watch dog time and rate of close window to watchdog time.
The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)
This setting is active for WDI or SPI control in the same time.

■ Address(WDTIME): 17H

A5	A4	A3	A2	A1	A0
0	1	0	1	1	1

■ Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	-	CWSET (1:0)		WDTIME (1:0)	

■ Setting contents
Below table shows OW and CW time setting.

CWSET (1:0)		Setting time
D3	D2	
0	0	CW rate: 0% *
0	1	CW rate: 25%
1	0	CW rate: 50%
1	1	CW rate: 75%

* Default setting

WDTIME (1:0)		Setting time
D1	D0	
0	0	WD time: 6ms
0	1	WD time: 12ms *
1	0	WD time: 24ms
1	1	WD time: 48ms

* Default setting

Cautions 1: CWSET is not available in “Advanced mode” (CW time is 50% fixed)
2: CWSET and WDTIME are only rewritable registers in FW.

➢ Evaluation value
The accumulated value of QA monitoring is read via this register.

■ Address(QAEVA): 19H

A5	A4	A3	A2	A1	A0
0	1	1	0	0	1

■ Register

Do7	Do6	Do5	Do4	Do3	Do2	Do1	Do0
ACCVA (7:0)							

- Accumulated valued for reset
  This register is a threshold value to occur the reset
  - Address(RSTVA): 1CH

A5	A4	A3	A2	A1	A0
0	1	1	1	0	0

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
SETVA (7:0)							

  - Setting contents
    Any numbers are allowed to set this register. The default value of this register is “255”.
    But the setting number of “zero” is prohibited for occurring the reset in “Advanced mode” selected in the configuration register.

4.8.5. Electrical characteristic

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
First window time	Tfw		57.6	64.0	70.4	ms
Watch dog time1	Twd1	WDTIME (1:0) = (0,0)	5.4	6.0	6.6	ms
Watch dog time2	Twd2	WDTIME (1:0) = (0,1)	10.8	12.0	13.2	ms
Watch dog time3	Twd3	WDTIME (1:0) = (1,0)	21.6	24.0	26.4	ms
Watch dog time4	Twd4	WDTIME (1:0) = (1,1)	43.2	48.0	52.8	ms

WDI pulse width

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Minimum pulse width	Twwdi	CWSET(1:0)=(0,0)	4.0			µs

4.9. Reset

The PMIC generates reset signal. RSTB pin is an open drain configuration including the pull-up resistor.

4.9.1. Reset factor

There are several cases to force reset happen. The reset signal is occurred by the following case. The reset factors are stored in RSTFAC. The detail is described in section 4.9.2

Table 4-2 Reset factor

Reset factors	Symbol	Remark
ERROR	STPERR	If RSTERR is set to 1
WDT, Advanced mode	OVADV	ACCVA (7:0) > SETVA (7:0)
Low voltage detection of VOUT1	LVLDO1	
WDT, Trigger in CW	WDSUS	
WDT, Expired watch dog time, OW	WDEXP	
Thermal shut down	TSDTMP	
Low voltage detection core voltage	LVCORE	See Figure 4-38

- Battery voltage
  The PMIC outputs the reset to prevent the error operation of the PMIC when the battery voltage falls down Vdbu (3.65V TYP.).
- LDO1 output
  The output voltage downs to Vd1l2 (3.11V TYP.) supply voltage down such as crank pulse situation or over current sinks from LDO1's output. These situations are regarded as unusual condition so that the PMIC generate reset signal. Refer to section 4.12.
- No first trigger to start WDT operation
  After initial reset is released, the PMIC generates 2ms reset pulse if no trigger is entered in FW. After reset, the PMIC waits a trigger in FW. Refer to section 4.8.
- WD trigger in Close Window period
  After WDT is started, the PMIC outputs reset if the refresh request in CW period. Refer to section 4.8.
- WD timer expires in Open Window
  After WDT is started, No WD trigger in OW period and WD timer is expired. The PMIC generates the reset. Refer to section 4.8.
- Reach the designated number in QA monitoring
  In "Advanced mode" of WDT operation, the evaluation register has accumulated the evaluation value. If the value reaches designated number, the PMIC generates 2ms reset pulse. Refer to section 4.8.3.
- Thermal shut down (THSD)
  The PMIC generates the reset if the junction temperature is over Tsd (section 4.13)
- Microcontroller's safety monitor
  The PMIC monitors ERROR pin indicating the MCU's safety operation. If the system needs reset when ERROROUT pin of MCU indicates unusual situations, Set configuration register (CONF). Refer to section 4.10.
- ENIG, EN
  Once either ENIG or EN are set to high, the PMIC starts its operation. When both ENIG and EN turn to low, reset occurs. Refer to section 4.1.
- Low voltage detection of core voltage
  The PMIC generates the rese if core voltage falls down Vdcol1 (1.13V TYP.). Refer to section 4.12.

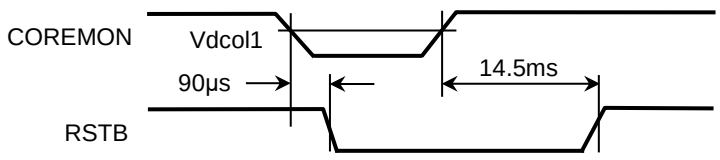


Figure 4-38 Timing of reset and core voltage

4.9.2. Reset factor register

The reset factors are lined up in this register. The register only is initialized at the PMIC power up.

- Reset factor register
  - Address(RSTFAC): 12H

A5	A4	A3	A2	A1	A0
0	1	0	0	1	0

  - Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
-	STPERR	OVADV	LVCORE	TSDTMP	WDEXP	WDSUS	LVLDO1

  - Contents

Bit	Contents
0	Normal *
1	Reset

* Default setting

- Reset factor clear
  - Address(RSTFCL): 13H

A5	A4	A3	A2	A1	A0
0	1	0	0	1	1

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	CLSTPERR	CLOVADV	CLLVCORE	CLTSDTMP	CLWDEXP	CLWDSUS	CLLVLDO1

  - Contents

Register name		Control contents	Setting	
			1	0 *
CLSTPERR	D6	Clear STPERR to 0	Clear	Not clear
CLOVADV	D5	Clear OVADV to 0	Clear	Not clear
CLLVCORE	D4	Clear LVCORE to 0	Clear	Not clear
CLTSDTMP	D3	Clear TSDTMP to 0	Clear	Not clear
CLWDEXP	D2	Clear WDEXP to 0	Clear	Not clear
CLWDSUS	D1	Clear WDSUS to 0	Clear	Not clear
CLLVLDO1	D0	Clear LVLDO1 to 0	Clear	Not clear

* Default setting

Note: INTOUT doesn't change low during 500µs after any reset factors are cleared. If any interrupt factors are occurred after 500µs, INTOUT is set to low.

➢ Reset factor mask
The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

■ Address(RSTFMSK): 14H

A5	A4	A3	A2	A1	A0
0	1	0	1	0	0

■ Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	MSKOVADV	-	MSKTSDTMP	MSKWDEXP	MSKWDSUS	-

■ Contents

Register name		Control contents	Setting	
			1	0 *
MSKOVADV	D5	Mask OVADV	Mask	Not mask
MSKTSDTMP	D3	Mask TSDTMP	Mask	Not mask
MSKWDEXP	D2	Mask WDEXP	Mask	Not mask
MSKWDSUS	D1	Mask WDSUS	Mask	Not mask

* Default setting

Caution: No reset corresponding with the reset factor by setting the mask register.

4.9.3. Software reset

Even though no reset factors exist, the PMIC can make reset pulse via SPI.

➢ Software reset
The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

■ Address(SFTRST): 1DH

A5	A4	A3	A2	A1	A0
0	1	1	1	0	1

■ Register

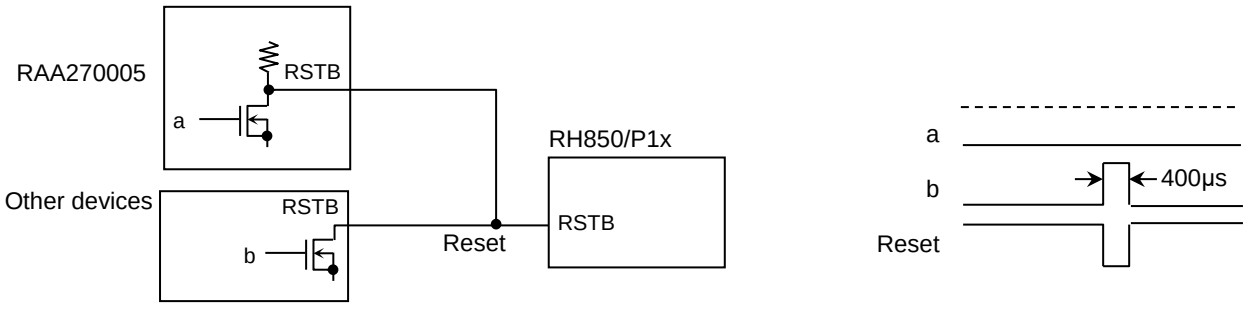
D7	D6	D5	D4	D3	D2	D1	D0
RDMKEY (7:0)							

■ Setting contents

- Enter the Data obtained by reading PRTCT register into RDMKEY

4.9.4. External reset

RSTB is open drain configuration and is able to be wired to the reset pin of other devices. (See below figure). The other reset should be also open drain. More than 400µs of forced reset is required to avoid an accidental reset of other devices. The registers which “Reset by” item is described as RSTB in section 4.2.5, are initialized by an external reset.



(a) Wired reset (b) Narrow reset pulse

Figure 4-39 Wired reset

4.9.5. Electrical characteristics

◆ Reset timing1

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Reset release time	Tdrstb	From initial INTOUT rising	13.0	14.5	16.0	ms
Reset pulse width	Twrstb		1.8	2.0	2.2	ms
Forced reset period	Tintrstb	External forced reset	360	400	440	µs

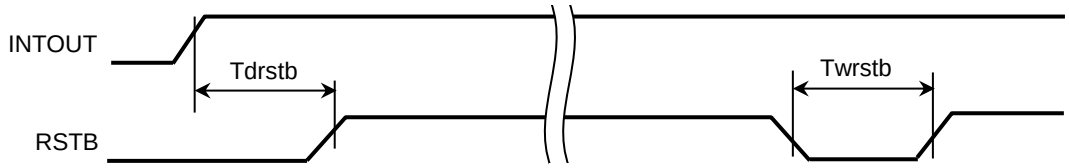


Figure 4-40 RSTB signal timing

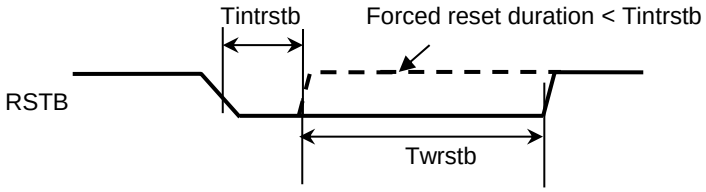


Figure 4-41 Forced reset duration for internal reset

4.10. Specified output pins

The PMIC has some specified digital output pins served safety operation in the entire system. The operation of each pin is described in below. These pins are set high and low by SPI.

4.10.1. Low voltage indicator (SUSP)

VOUT1 normally starts up and the reset is high, then SUSP goes to high. When VOUT1 applied for MCU falls below Vd1l1 level, SUSP asserts low. VOUT1 goes up the returned voltage (Vr1l) after SUSP is low, SUSP asserts high. The detail detection level is shown in section 4.12.4. If SUSP asserts low, WDT is stopped and the WDT state enters FW after SUSP is returned high.

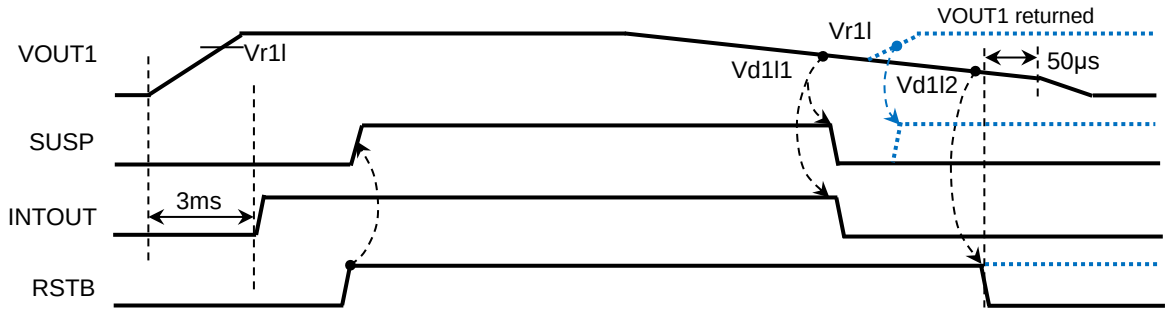


Figure 4-42 SUSP timing

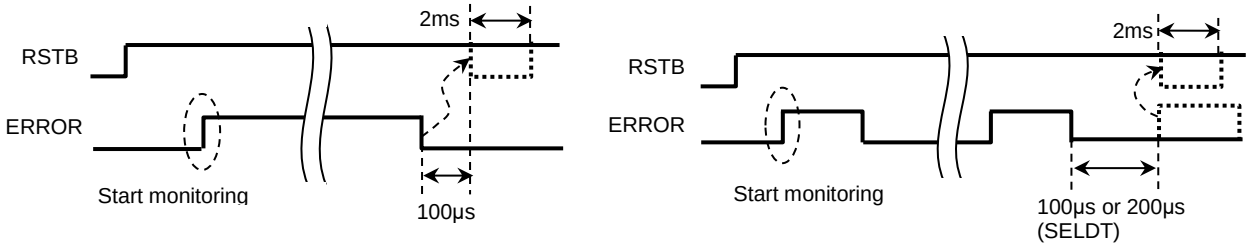
4.10.2. Error input (ERROR)

The ERROROUT pin in a RH850/P1x MCU indicates the unusual situation in the MCU. The detail of ERROROUT is referred to the user's manual of RH850/P1x.

ERROR receives the error indication signal of MCU. If the reset is required when ERROR indicates the any error (the dash line in Figure 4-43), set the configuration register (CONF).

There are two kinds of format in unusual signal: static operation and dynamic operation. Select signal format to determine the unusual situation in MCU. If the static level is selected, low level on ERROR indicates error occurred in MCU and the PMIC makes RSTB assert low. If ERMODE is set to 1 and ERROR monitor is the dynamic mode, no toggling indicates error occurred in MCU. And the PMIC detects no toggling during 100µs or 200µs and makes RSTB assert low as well. In the initial operation, after ERROR signal is set to high, the PMIC starts monitoring ERROR pin.

Note: Toggling time needs to be 100µs+/-10µs or 200µs+/-20µs.

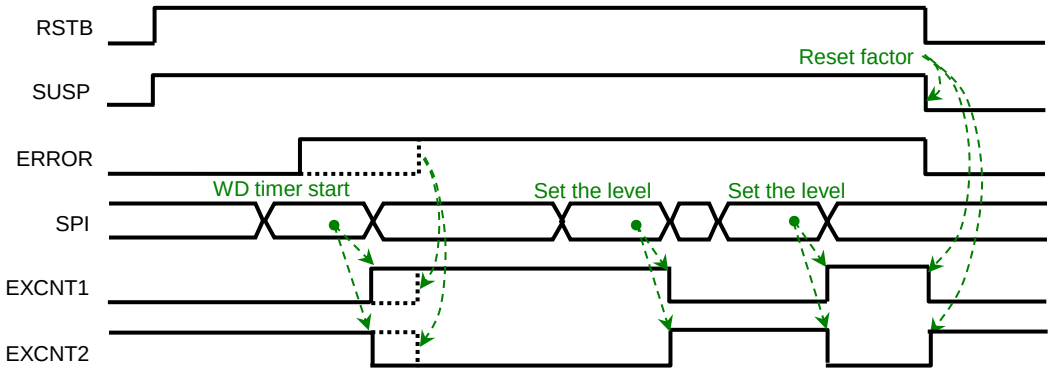


(a) Static mode (b) Dynamic mode

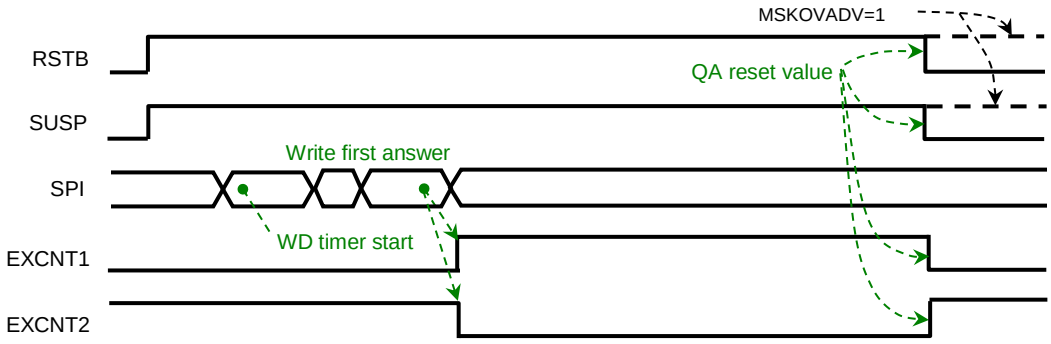
Figure 4-43 ERROR behavior

4.10.3. External control (EXCNT1/2)

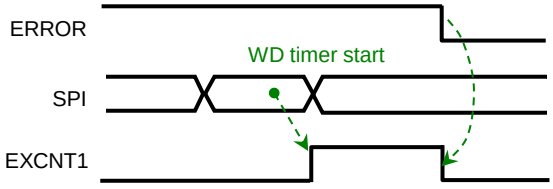
In order to control another device through the PMIC, the PMIC has specified output pins, EXCNT1/2. EXCNT1 is set to high after WDT is requested to start and ERROR monitoring is stared. EXCNT2 is set to high after self-diagnosis and set to low after WDT is requested to start and ERROR monitoring is stared. The reset factor is occurred or SUSP is set to low makes EXCNT1/2 level is changed.
In “Advanced mode” for WD, EXCNT1/2 is normal output after QA monitoring is started. EXCNT1/2 level is changed by reset factor of RSTVA. EXCNT1/2 links to ERROR, EXCNT1/2 is changed by error input. These pins control can be done via SPI as well.
EXCNT1/2 aren’t changed the level even if masking these reset factor (the factor by ERROR or WDT).



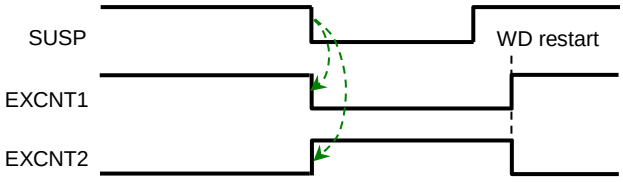
(a) WD normal mode



(b) WD “Advanced mode”



(c) ERROR (Refer to section 4.10.2)



(d) SUSP (Refer to section 4.10.1)

Figure 4-44 EXCNT1/2 operation

◆ EXCNT2 output delay

The delay of EXCNT2, low to high, is selectable to the maximum 15ms. EXCNT2 goes to high after this selected delay time if SUSP goes back to high in that delay period. The delay setting of EXCNT2 is ignored in SETEXCNT2 setting.

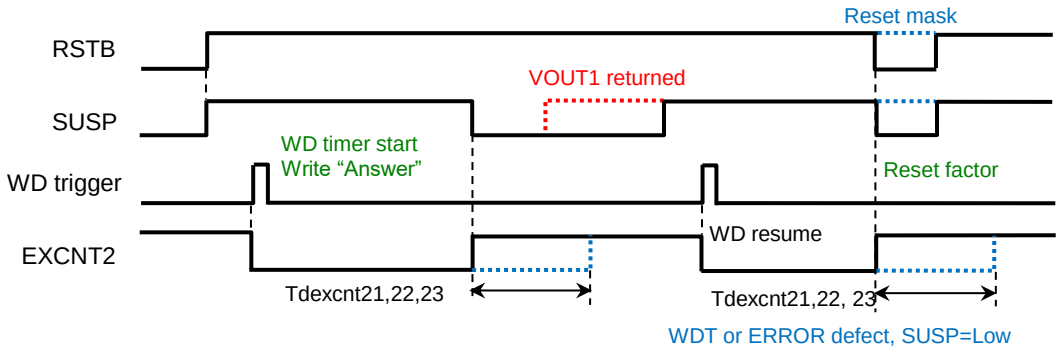


Figure 4-45 Output delay time of EXCNT2

Table 4-3 EXCNT1/EXCNT2 Control

	Condition	EXCNT1	EXCNT2	Note
(1)	EXCNT start 1. After WDT, ERROR monitoring 2. After ERROR monitoring, WDT start	1	0	WDT start 1. WDI/SPI : Trigger in FW 2. ADV: First trigger in OW
(2)	RSTB=L	0	1 (without delay)	
(3)	WDT Error (Trigger in CW, OW timeout Over SETVA)	0	1 (with delay)	MSKOVADV/MSKWDEXP /MSKWDSUS =1
(4)	ERROR	0	1 (with delay)	RSTERR=0
(5)	SUSP=L	0	1 (with delay)	
(6)	Control by SETEXCNT1/2	0/1	1/0 (without delay)	Enable after (1) EXCNT start. Condition (2) to (5) takes precedence.

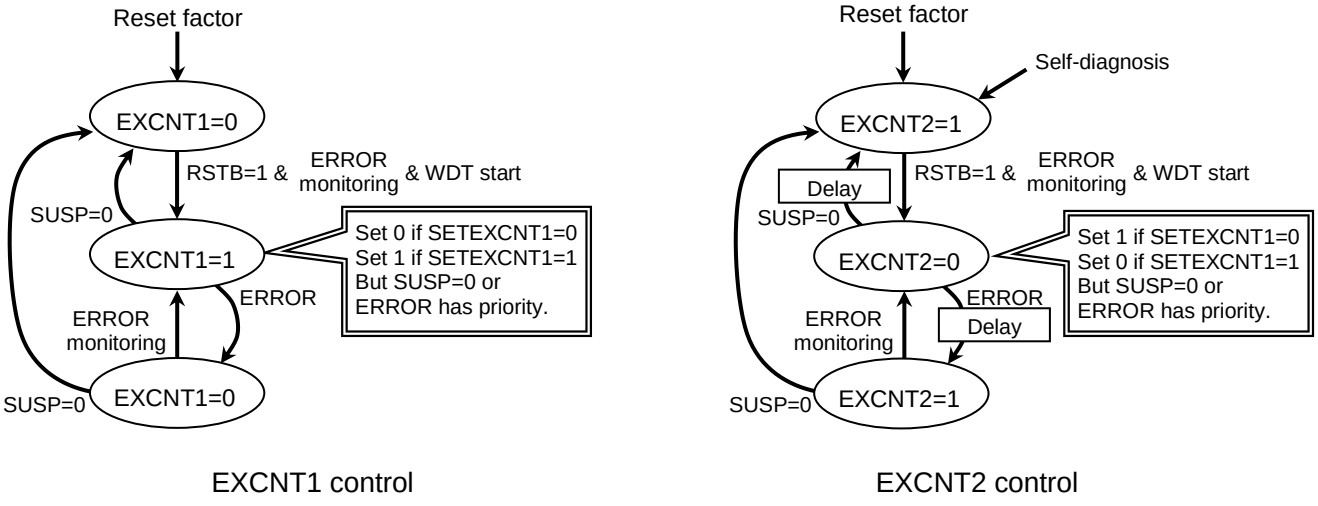


Figure 4-46 EXCNT1/2 control flow

4.10.4. Backup-power control (BKCNT)

BKCNT is the control signal to maintain the system function if the PMIC occurs the event in Table 4-4 by any unusual situation when the VINR is over Vrbku. The backup-power supplies the power to MCU after BKCNT outputs high once. The PMIC set BKMODE 1 and INTOUT is low. BKCNT keeps high until the PMIC goes to stand-by state.

Table 4-4 Backup-power switching factor

Switching factor	Description
DETDCU	Over voltage detection of buck DCDC
DETDCL	Low voltage detection of buck DCDC
DETDCOC	Over current detection of buck DCDC
DET1L1	Low voltage detection of LDO1

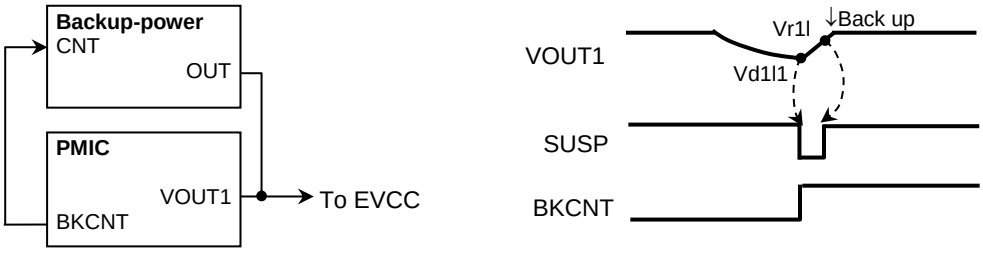


Figure 4-47 Backup-power control

4.10.5. Register

Registers for each pin setting

- Pin function setting
  - Address(PINSET): 15H

A5	A4	A3	A2	A1	A0
0	1	0	1	0	1

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	DEXCNT2(1:0)		-	-	SELDT	ERMODE

  - Setting contents

The rising delay time of EXCNT2

DEXCNT2(1:0)		EXCNT2 rising delay time
D5	D4	
0	0	0ms *
0	1	5ms
1	0	10ms
1	1	15ms

* Default setting

Mode setting of ERROR pin

Register name		Control contents	Setting	
			1	0
SELDT	D1	ERROR toggle expire time	100µs	200µs *
ERMODE	D0	Error indication mode	Dynamic	Static *

* Default setting

- Pin setting

The digital pins are forced to control by registers.
This register is secured registers. Enter “key” code before entering this request. (Refer to section 4.2.3.)

  - Address(SETDPIN): 02H

A5	A4	A3	A2	A1	A0
0	0	0	0	1	0

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	-	SETEXCNT2	SETEXCNT1	SETSUSP	SETBKCNT

  - Setting contents

Register name		Control contents	Setting	
			1	0
SETEXCNT2	D3	Pin setting of EXCNT2	Normal	High *
SETEXCNT1	D2	Pin setting of EXCNT1	Normal	Low *
SETSUSP	D1	Pin setting of SUSP	Normal *	Low
SETBKCNT	D0	Pin setting of BKCNT	High	Normal *

* Default setting

Notes1: Refer to section 4.10.3 to “Normal”

2: SETEXCNT2: WDT is activated, this setting is enable after EXCNT2 outputs low. Write “0” if forcing EXCNT2 high.

3: SETEXCNT1: WDT is activated, this setting is enable after EXCNT1 outputs high. Write “0” if forcing EXCNT1 low.

4: SETSUSP: VOUT1 starts normally, this setting is enable after SUSP outputs high. Write “0” if forcing SUSP low.

5: SETBKCNT: Write “1” if forcing BKCNT high.

4.10.6. Electrical characteristics

◆ SUSP minimum low width

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
SUSP min. low width	Twsusp	SUSP returned	428	476	523	ns

◆ EXCNT2 output delay

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
EXCNT2 output delay	Tdexcnt21	DEXCNT2(1:0) =01, see Figure 4-45	4.5	5.0	5.5	ms
	Tdexcnt22	DEXCNT2(1:0) =10, see Figure 4-45	9.0	10.0	11.0	ms
	Tdexcnt23	DEXCNT2(1:0) =11, see Figure 4-45	13.5	15.0	16.5	ms

4.11. Interrupt Signal

The purpose of interrupt signal is to inform what happened inside the PMIC to MCU. The INTOUT pin indicates that interrupt factor is occurred and MCU identify what interrupt factor is via SPI.

4.11.1. Interrupt control

When an interrupt factor happens, the interrupt signal is asserted low. The information of interrupt factor is stored into interrupt registers and MCU can read what the interrupt factor is. The interrupt registers are cleared by the writing clear registers. If several interrupt factors are stored, needs to clear all clear registers which cause interrupt assertion.
The interrupt informing can be suspended by setting the interrupt mask registers. After setting these registers, the interrupt is not asserted even though the interrupt factor is occurred.

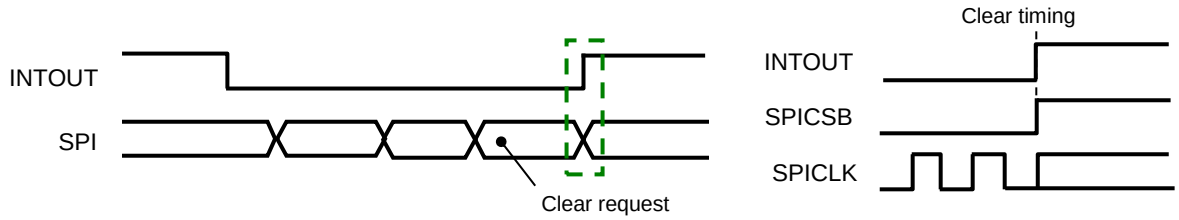


Figure 4-48 Interrupt clear timing

4.11.2. Interrupt factors

The interrupt factors are listed below. Interrupt bit names are indicated as symbol.
After 500us passed from the point when interrupt cleared, if interrupt factor remains such situation, INTOUT asserts low again.

Table 4-5 List of interrupt factors

Interrupt factor		Symbol	Note
Interrupt factor1	Over current detection on TRACK2	DETTRQ2OC	
	Over current detection on TRACK1	DETTRQ1OC	
	Over current detection on boost DCDC	DETBSOC	
	Short GND detection on core voltage	DETCOL	
	Low voltage detection on TRACK2	DETTRQ2L	
	Low voltage detection on TRACK1	DETTRQ1L	
	Low voltage detection on VOUT1	DET1L	
	Low voltage detection on buck DCDC	DETDCL	
Interrupt factor2	Over voltage detection1 on MCU core voltage	DETCOU1	Core voltage, Absolute maximum voltage
	Over voltage detection2 on MCU core voltage	DETCOU2	Core voltage, Functional voltage
	Over voltage detection on TRACK2	DETTRQ2U	
	Over voltage detection on TRACK1	DETTRQ1U	
	Over voltage detection on VOUT1	DET1U	
	Over voltage detection buck DCDC	DETDCU	
Interrupt factor3	Notification to backup-power changing	BKMODE	
	Self-diagnosis of backup-power	SDBKUP	Check backup-power
	Self-diagnosis of state machine	SDSTA	Diagnosis during operation
	Self-diagnosis of oscillator	SDOSC	
	Battery voltage	BATBK	Backup-power functional condition (If self-diagnosis error, INTOUT is set to low)
	Self-diagnosis (LDO0, BGR)	DETREF	
	High temperature warning	WRTMP	
	Over current detection on buck DCDC	DETDCOC	

Interrupt factor (Continued)

Interrupt factor		Symbol	Note
4	Monitoring of digital output, EXCNT1/2	PEXCNT1/2	Output monitoring
	Monitoring of digital output, SUSP	PSUSP	Output monitoring
	Monitoring of digital output, BKCNT	PBKCNT	Output monitoring
	Monitoring of digital output, RSTB	PRSTB	Output monitoring

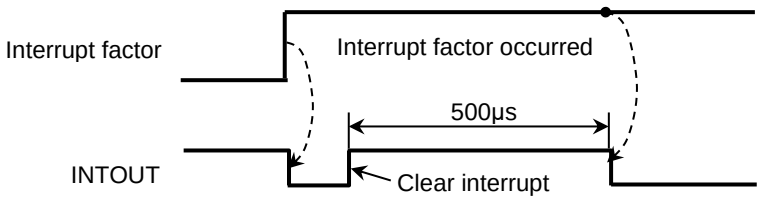


Figure 4-49 INTOUT behavior, continuous interrupt factors

Note: INTOUT doesn't change low during 500µs after any interrupt factors are cleared.
If any interrupt factors are occurred after 500µs, INTOUT is set to low.

4.11.3. Register

Interrupt registers indicate the factor that causes INTOUT assertion. Even one or more interrupt factors are occurred, INTOUT asserts low. If the mask resisters are set, no interrupt related with those factors is occurred.

- Interrupt factor
  This register indicates what interrupt register occurs so that it can read interrupt factor directly. INTSD register is indicated fail occurred in self-diagnosis. And if the factor belonged in each interrupt request address failed in self-diagnosis, D2-D0 is set "1" simultaneously. If the digital pins control unmatched to this output, D3 is set "1". INTRSFG register is indicated the factor which makes reset exists. This register is cleared by clearing the occurred interrupt factor.

■ Address(INTFAC): 03H

A5	A4	A3	A2	A1	A0
0	0	0	0	1	1

■ Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
-	-	INTRSFG	INTSD	INTR4	INTR3	INTR2	INTR1

■ Contents

Register name		Control contents	Setting	
			1	0
INTRSFG	D5	Flags of reset factor	Reset flags	No reset flag*
INTSD	D4	Interrupt factor in self-diagnosis	Interrupt	No interrupt *
INTR4	D3	Interrupt factor in INTREQ4	Interrupt	No interrupt *
INTR3	D2	Interrupt factor in INTREQ3	Interrupt	No interrupt *
INTR2	D1	Interrupt factor in INTREQ2	Interrupt	No interrupt *
INTR1	D0	Interrupt factor in INTREQ1	Interrupt	No interrupt *

* Default setting

➢ Interrupt request1
Interrupts of low voltage detection are collected in this address.
The interrupt request by the fail detection in the self-diagnosis is occurred in corresponding block.

■ Address(INTREQ1): 04H

A5	A4	A3	A2	A1	A0
0	0	0	1	0	0

■ Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
DETTRQ2OC	DETTRQ1OC	DETBSOC	DETCOL	DETTRQ2L	DETTRQ1L	DET1L	DETDCL

■ Contents

Bit	Contents
0	No interrupt request*
1	Interrupt request

* Default setting

➢ Interrupt request2
Interrupts of over voltage detection are collected in this address.
The interrupt request by the fail detection in the self-diagnosis is occurred in corresponding block.

■ Address(INTREQ2): 05H

A5	A4	A3	A2	A1	A0
0	0	0	1	0	1

■ Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
-	-	DETCOU2	DETCOU1	DETTRQ2U	DETTRQ1U	DET1U	DETDCU

■ Contents

Bit	Contents
0	No interrupt request*
1	Interrupt request

* Default setting

➢ Interrupt request3
Other interrupt factors are collected in this address.

■ Address(INTREQ3): 06H

A5	A4	A3	A2	A1	A0
0	0	0	1	1	0

■ Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
BKMODE	SDBKUP	SDSTA	SDOSC	BATBK	DETREF	WRTMP	DETDCOC

■ Contents

Bit	Contents
0	No interrupt request*
1	Interrupt request

* Default setting

➢ Interrupt request4
Interrupt factors of digital output are collected in this address.

■ Address(INTREQ4): 07H

A5	A4	A3	A2	A1	A0
0	0	0	1	1	1

■ Register (Read only)

D7	D6	D5	D4	D3	D2	D1	D0
DUMMY	-	-	PEXCNT2	PEXCNT1	PSUSP	PBKCNT	PRSTB

Note: D7: DUMMY bit accepts a write request.

■ Contents

Bit	Contents
0	No interrupt request*
1	Interrupt request

* Default setting

Note: D7: DUMMY bit, for confirming INTOUT pin, is “read/write”. Set to 0 to DUMMY after interrupting DUMMY.

➢ Interrupt clear1
Clear for “INTREQ1” register is placed in this address. If all contents of this address are cleared, INTOUT is asserted high.

■ Address(INTCL1): 08H

A5	A4	A3	A2	A1	A0
0	0	1	0	0	0

■ Register (Write only)

D7	D6	D5	D4	D3	D2	D1	D0
CLTRQ2OC	CLTRQ1OC	CLBSOC	CLCOL	CLTRQ2L	CLTRQ1L	CL1L	CLDCL

■ Contents

Register name		Control contents	Setting	
			1	0 *
CLTRQ2OC	D7	Clear DETTRQ2OC to 0	Clear	Not clear
CLTRQ1OC	D6	Clear DETTRQ1OC to 0	Clear	Not clear
CLBSOC	D5	Clear DETBSOC to 0	Clear	Not clear
CLCOL	D4	Clear DETCOL to 0	Clear	Not clear
CLTRQ2L	D3	Clear DETTRQ2L to 0	Clear	Not clear
CLTRQ1L	D2	Clear DETTRQ1L to 0	Clear	Not clear
CL1L	D1	Clear DET1L 0 to 0	Clear	Not clear
CLDCL	D0	Clear DETDCL to 0	Clear	Not clear

* Default setting

➢ Interrupt clear2
Clear for “INTREQ2” register is placed in this address. If all contents of this address are cleared, INTOUT is asserted high.

■ Address(INTCL2): 09H

A5	A4	A3	A2	A1	A0
0	0	1	0	0	1

■ Register (Write only)

D7	D6	D5	D4	D3	D2	D1	D0
-	-	CLCOU2	CLCOU1	CLTRQ2U	CLTRQ1U	CL1U	CLDCU

■ Contents

Register name		Control contents	Setting	
			1	0 *
CLCOU2	D5	Clear DETCOU2 to 0	Clear	Not clear
CLCOU1	D4	Clear DETCOU1 to 0	Clear	Not clear
CLTRQ2U	D3	Clear DETTRQ2U to 0	Clear	Not clear
CLTRQ1U	D2	Clear DETTRQ1U to 0	Clear	Not clear
CL1U	D1	Clear DET1U to 0	Clear	Not clear
CLDCU	D0	Clear DETDCU to 0	Clear	Not clear

* Default setting

➢ Interrupt clear3
Clear for “INTREQ3” register is placed in this address. If all contents of this address are cleared, INTOUT is asserted high.

■ Address(INTCL3): 0AH

A5	A4	A3	A2	A1	A0
0	0	1	0	1	0

■ Register (Write only)

D7	D6	D5	D4	D3	D2	D1	D0
CLBKMODE	CLBKUP	CLSDSTA	CLSDOSC	CLBATBK	CLREF	CLWRTMP	CLDCOC

■ Contents

Register name		Control contents	Setting	
			1	0 *
CLBKMODE	D7	Clear BKMODE to 0	Clear	Not clear
CLBKUP	D6	Clear SDBKUP to 0	Clear	Not clear
CLSDSTA	D5	Clear SDSTA to 0	Clear	Not clear
CLSDOSC	D4	Clear SDOSC to 0	Clear	Not clear
CLBATBK	D3	Clear BATBK to 0	Clear	Not clear
CLREF	D2	Clear DETREF to 0	Clear	Not clear
CLWRTMP	D1	Clear WRTMP to 0	Clear	Not clear
CLDCOC	D0	Clear DETDCOC to 0	Clear	Not clear

* Default setting

➢ Interrupt clear4
Clear for “INTREQ4” register is placed in this address. If all contents of this address are cleared, INTOUT is asserted high.

■ Address(INTCL4): 0BH

A5	A4	A3	A2	A1	A0
0	0	1	0	1	1

■ Register (Write only)

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	CLPEXCNT2	CLPEXCNT1	CLPSUSP	CLPBKCNT	CLPRSTB

■ Contents

Register name		Control contents	Setting	
			1	0 *
CLPEXCNT2	D4	Clear PEXCNT2 to 0	Clear	Not clear
CLPEXCNT1	D3	Clear PEXCNT1 to 0	Clear	Not clear
CLPSUSP	D2	Clear PSUSP to 0	Clear	Not clear
CLPBKCNT	D1	Clear PBKCNT to 0	Clear	Not clear
CLPRSTB	D0	Clear PRSTB to 0	Clear	Not clear

* Default setting

➢ Interrupt mask1
Interrupt mask for “INTR1” register is placed in this address.
The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

■ Address(INTMSK1): 0CH

A5	A4	A3	A2	A1	A0
0	0	1	1	0	0

■ Register

D7	D6	D5	D4	D3	D2	D1	D0
MSKTRQ2OC	MSKTRQ1OC	MSKBSOC	-	MSKTRQ2L	MSKTRQ1L	MSK1L	MSKDCL

■ Contents

Register name		Control contents	Setting	
			1	0 *
MSKTRQ2OC	D7	Mask DETTR2OC	Masked	Not masked
MSKTRQ1OC	D6	Mask DETTR1OC	Masked	Not masked
MSKBSOC	D5	Mask DETBSOC	Masked	Not masked
MSKTRQ2L	D3	Mask DETTRQ2L	Masked	Not masked
MSKTRQ1L	D2	Mask DETTRQ1L	Masked	Not masked
MSK1L	D1	Mask DET1L	Masked	Not masked
MSKDCL	D0	Mask DETDCL	Masked	Not masked

* Default setting

Notes1: BKCNT isn’t high by setting MSKDCL to high.
2: BKCNT isn’t high and SUSP isn’t low by setting MSK1L to high.
3: The TRACK1/2 output in low voltage detection keeps ON during setting MSKTRQ1L/2L to high.
4: The TRACK1/2 output in over current detection keeps ON during setting MSKTRQ1OC/2OC to high.

➢ Interrupt mask2
Interrupt mask for “INTR2” register is placed in this address.
The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

■ Address(INTMSK2): 0DH

A5	A4	A3	A2	A1	A0
0	0	1	1	0	1

■ Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	MSKCOU2	MSKCOU1	MSKTRQ2U	MSKTRQ1U	MSK1U	MSKDCU

■ Contents

Register name		Control contents	Setting	
			1	0 *
MSKCOU2	D5	Mask DETCOU2	Masked	Not masked
MSKCOU1	D4	Mask DETCOU1	Masked	Not masked
MSKTRQ2U	D3	Mask DETTRQ2U	Masked	Not masked
MSKTRQ1U	D2	Mask DETTRQ1U	Masked	Not masked
MSK1U	D1	Mask DET1U	Masked	Not masked
MSKDCU	D0	Mask DETDCU	Masked	Not masked

* Default setting

Notes1: BKCNT isn’t high by setting MSKDCU to high.
2: The LDO1 isn’t suspended and BKCNT is high in the backup-power by setting MSKCOU1 to high.

➢ Interrupt mask3
Interrupt mask for “INTR3” register is placed in this address.
The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

■ Address(INTMSK3): 0EH

A5	A4	A3	A2	A1	A0
0	0	1	1	1	0

■ Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	MSKSDSTA	MSKSDOSC	-	MSKREF	MSKWRTMP	MSKDCOC

■ Contents

Register name		Control contents	Setting	
			1	0 *
MSKSDSTA	D5	Mask SDSTA	Masked	Not masked
MSKSDOSC	D4	Mask SDOSC	Masked	Not masked
MSKREF	D2	Mask DETREF	Masked	Not masked
MSKWRTMP	D1	Mask WRTMP	Masked	Not masked
MSKDCOC	D0	Mask DETDCOC	Masked	Not masked

* Default setting

Note: BKCNT isn’t high by setting MSKDCOC to high.

- Interrupt mask4
  Interrupt mask for “INTR4” register is placed in this address.
  The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

■ Address(INTMSK4): 0FH

A5	A4	A3	A2	A1	A0
0	0	1	1	1	1

■ Register

D7	D6	D5	D4	D3	D2	D1	D0
-	-	-	MSKPEXCNT2	MSKPEXCNT1	MSKPSUSP	MSKPBKCNT	MSKPRSTB

■ Contents

Register name		Control contents	Setting	
			1	0 *
MSKPEXCNT2	D4	Mask PEXCNT2	Masked	Not masked
MSKPEXCNT1	D3	Mask PEXCNT1	Masked	Not masked
MSKPSUSP	D2	Mask PSUSP	Masked	Not masked
MSKPBKCNT	D1	Mask PBKCNT	Masked	Not masked
MSKPRSTB	D0	Mask PRSTB	Masked	Not masked

* Default setting

4.12. Functional Safety

The PMIC has a sort of protect function for a functional safety to protect MCU or the PMIC from extraordinary accident.

4.12.1. Voltage detection

The buck DCDC, LDOs and trackers have voltage detectors. And a battery voltage detector has same function as well.

◆ **High and low voltage detection1**

Over and low voltage detection behaviors are shown in Figure 4-50. When over or low voltage is detected, INTOUT is asserted low.

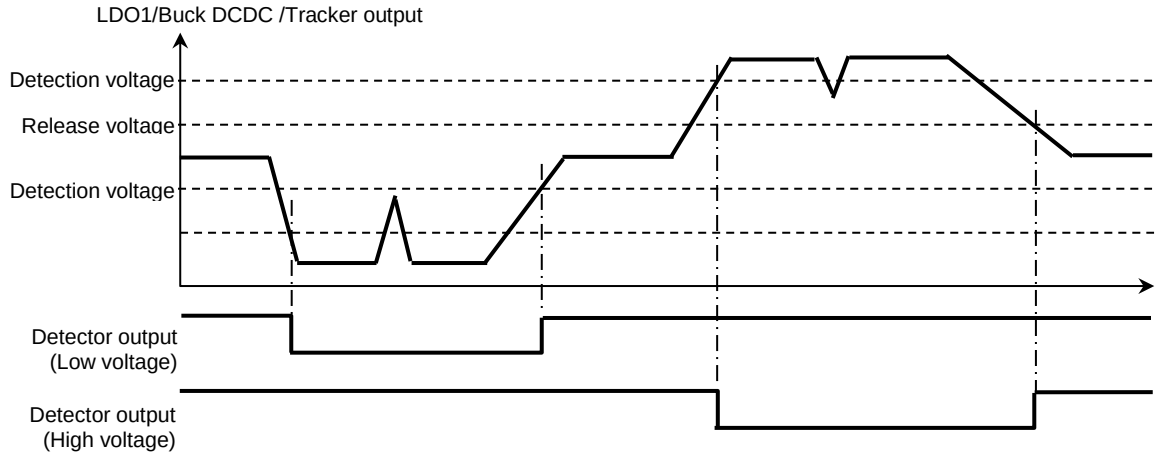


Figure 4-50 Over and low voltage detector's behavior

◆ **High and low voltage2**

In the core voltage monitoring, the over (Vdcou2) and low (Vdcol1/2) voltage detection policy are different from the above behavior.

The detectors have no release level and have anti glitch circuit to prevent nuisance reset.

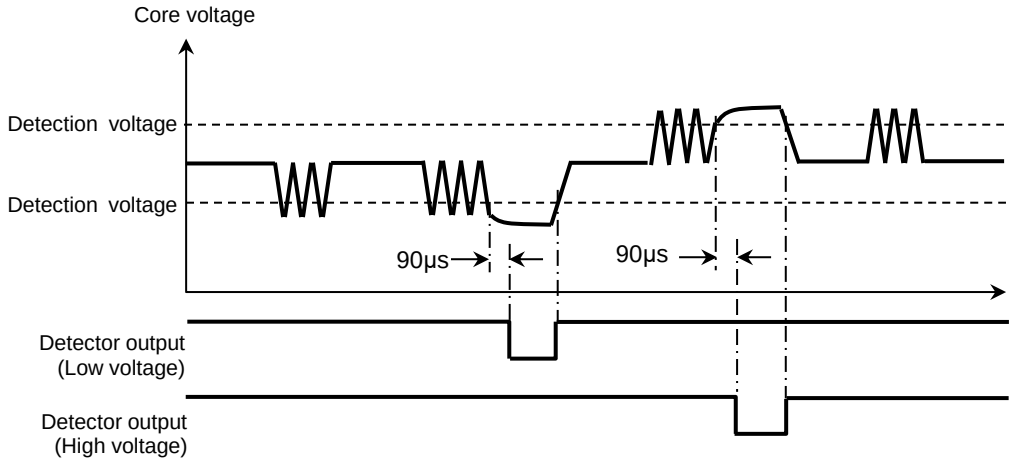


Figure 4-51 Over and low voltage detector's behavior for core voltage

4.12.2. PMIC behavior after unusual detection

The PMIC have some over or low voltage, over current detectors and temperatures sensors. The behaviors in case of unusual detections are summarized below table.

Table 4-6 PMIC behavoir list in unusal conditons

Unusual detection	Description	Behavior of the PMIC
DETBAT	Low voltage detection of battery	Output reset signal
DETDCU	Over voltage detection of buck DCDC	Stop Buck DCDC switching INTOUT: Low BKCNT: High*
DETDCL	Low voltage detection of buck DCDC	Enter interval operating of buck DCDC INTOUT: Low BKCNT: High*
DETDCOC	Over current detection of buck DCDC	Enter interval operating of buck DCDC INTOUT: Low BKCNT: High*
DETBSOC	Over current detection of boost DCDC	INTOUT: Low
DET1U	Over voltage detection of LDO1	INTOUT: Low
DET1L1	Low voltage detection of LDO1	SUSP, INTOUT, EXCNT1: Low EXCNT2: High BKCNT: High*
DET1L2	Low voltage detection of LDO1	Enter P/D sequence after reset
DETCOU1	Over absolute maximum detection of core voltage	Suspend LDO1
DETCOU2	Over voltage detection of core voltage	INTOUT: Low
LVCORE	Low voltage detection of core voltage	Output reset, INTOUT: Low
DETCOL	Low voltage detection of core voltage	Suspend LDO1 Enter P/D sequence after reset INTOUT: Low, Refer to Figure 4-52
DETTRQ1U	Over voltage detection of TRACK1	INTOUT: Low
DETTRQ1L	Low voltage detection of TRACK1	INTOUT: Low Stop TRACK1
DETTRQ2U	Over voltage detection of TRACK2	INTOUT: Low
DETTRQ2L	Low voltage detection of TRACK2	INTOUT: Low Stop TRACK2
DETTRQ1OC	Over current detection of TRACK1	INTOUT: Low Stop TRACK1
DETTRQ2OC	Over current detection of TRACK2	INTOUT: Low Stop TRACK2
WRTMP	Warning temperature detection	INTOUT: Low
TSDTMP	Shut down temperature detection	INTOUT: Low Enter P/D sequence after reset

* If the backup power is detected

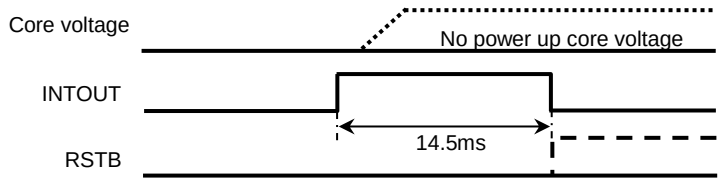


Figure 4-52 Low voltage detection behavior for core voltage at power up

4.12.3. Self-diagnosis

Built-in-self-test is implemented in the PMIC so that self-diagnostic of the PMIC's function is executed during initializing. The self-diagnostic is done to prevent serious situation such as applying unexpected voltage to MCU or communication disability with MCU. The following blocks are checked as self-diagnostic.

- Detectors: Confirm the over/low detection function of regulators
- Logic circuit: Confirm logic function
- Oscillator: Confirm if the oscillation frequency is expected
- Temperature sensor: Confirm the function of thermal shutdown
- Backup-power: Confirm with or without the backup voltage and output voltage

◆ **Detectors**

To make sure output voltage of each regulator, the detect functionality is tested before regulators power up. A voltage for comparator test is applied to the detector part. During diagnosis execution, detect function is checked by changing comparator's input. If any error is detected, INTOUT is asserted.

◆ **Logic circuit**

The logic circuit in the PMIC is checked before reset is released. The self-diagnosis is done by test circuit implemented in the PMIC. If any error is detected in self-diagnosis, the PMIC does not start to operate.

◆ **Oscillator**

The oscillator is used for not only switching in DCDC but also state machine. Any damage in the oscillator may affect PMIC function.

There are two oscillators which have quite same operation. They monitor oscillation each other, and if any unusual oscillation is detected then switched to the oscillator which acts usual operation. And then the PMIC set SDOSC to 1 and informs INTOUT assertion.

◆ **Temperature sensor**

The temperature sensor senses a voltage corresponding to the die temperature. During self-diagnosis period, the thermal shutdown function is checked. If any error is detected, INTOUT is asserted.

◆ **Backup-power**

The PMIC start up the backup-power by setting BKCNT is high once. The PMIC recognizes the backup-power if VOUT1 voltage is over DET1L. The PMIC starts the power up sequence after confirmation of the backup-power. SDBKUP set 1 if VOUT1 voltage is over Vr1l when BKCNT before LDO1 activation is low.

4.12.4. Electrical characteristics

The detection levels in each regulator are shown in below tables.

◆ **Battery voltage detector**

Table 4-7 Detection level of battery

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DETBAT						
Detection voltage	Vdbu	VINR	3.50	3.65	3.80	V
Release voltage	Vrbu	VINR	5.00	5.25	5.50	V
DETBATBK						
Detection voltage	Vrbku	VINR	7.40	7.70	8.00	V

◆ **Detector in buck DCDC**

Table 4-8 Detection level of buck DCDC

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DETDCU						
Detection voltage	Vddu		6.90	7.15	7.40	V
Release voltage	Vrdu		6.60	6.85	7.10	V
DETDCL						
Detection voltage	Vddl		2.70	2.85	3.00	V
Release voltage	Vrdl		4.40	4.60	4.80	V
DETDCOC						
Detection current	Iddcoc*		750	-	-	mA

*: Guaranteed by Design Engineering

◆ **Detector in boost DCDC**

Table 4-9 Detection level of boost DCDC

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DETBSOC						
Detection current	Idbsoc*	Current of 47mΩ(±5%)	2.2	-	2.7	A

*: Guaranteed by Design Engineering

◆ **Detector in LDO0**

Table 4-10 Detection level of LDO0

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DET0U						
Detection voltage	Vd0u		3.70	3.85	4.00	V
DET0L						
Detection voltage	Vd0l		3.000	3.081	3.164	V

◆ **Detector in LDO1**

Table 4-11 Detection level of LDO1

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DET1U						
Detection voltage	Vd1u		5.200	5.350	5.500	V
Release voltage	Vr1u		5.100	5.250	5.400	V
DET1L1						
Detection voltage	Vd1l1		4.500	4.625	4.750	V
Release voltage	Vr1l		4.650	4.775	4.900	V
DET1L2						
Detection voltage	Vd1l2		3.020	3.110	3.200	V

Note: RSTB is low if DET1L2 is detected.

◆ **Detector in TRACK1**

Table 4-12 Detection level of TRAK1

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DETTRQ1U						
Detection voltage	Vdtr1u	Based on VOUT1	104.0	107.0	110.0	%
Release voltage	Vrtr1u	Based on VOUT1	102.0	105.0	108.0	%
DETTRQ1L						
Detection voltage	Vdtr1l	TRQLVSEL=0, Based on VOUT1	47.0	48.6	50.2	%
		TRQLVSEL=1, Based on VOUT1	90.0	92.5	95.0	%
Detection voltage	Vrtr1l	Based on VOUT1	93.0	95.5	98.0	%
DETTRQ1OC						
Detection current	Idtr1oc		230	-	700	mA

◆ **Detector in TRACK2**

Table 4-13 Detection level of TRACK2

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DETTRQ2U						
Detection voltage	Vdtr2u	Based on VOUT1	104.0	107.0	110.0	%
Release voltage	Vrtr2u	Based on VOUT1	102.0	105.0	108.0	%
DETTRQ2L						
Detection voltage	Vdtr2l	TRQLVSEL=0, Based on VOUT1	47.0	48.6	50.2	%
		TRQLVSEL=1, Based on VOUT1	90.0	92.5	95.0	%
Detection voltage	Vrtr2l	Based on VOUT1	93.0	95.5	98.0	%
DETTRQ2OC						
Detection current	Idtr2oc		230	-	700	mA

◆ **Detector in core voltage**

Table 4-14 Detection level of core voltage

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
DETCOU1						
Detection voltage	Vdcou1		1.50	1.55	1.60	V
Release voltage	Vrcou1		1.42	1.48	1.53	V
DETCOU2						
Detection voltage	Vdcou2		1.35	1.38	1.40	V
LVCORE						
Detection voltage	Vdcol1		1.10	1.13	1.15	V
DETCOL						
Detection voltage	Vdcol2		0.90	0.95	1.00	V

Notes1: RSTB is low if LVCORE is detected

2: The PMIC enters the power down sequence if DETCOL is detected

4.13. Temperature sensor

Temperature sensors are implemented in the PMIC.

4.13.1. Thermal shutdown

For product safety, thermal shutdown functions are implemented. Temperature sensors detect a voltage corresponding to the internal temperature. When warning temperature is detected, INTOUT asserts low. The temperature sensors are placed near by buck DCDC, and LDO1. If one of these sensors detects high junction temperature, INTOUT asserts low and the reset signal is released and the PMIC execute power down sequence.
After the junction temperature goes down across the release temperature, the PMIC restarts in the power-up sequence. Resuming TRACK1 and TRACK2 operation requires that VTPQ1CNT and VTRQ2CNT are 1 due to initialize these registers.

Table 4-15 Thermal detection

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Warning temperature	Twng		140	160	180	°C
Shutdown temperature	Tsd		160	180	200	
Released temperature	Trls		125	145	165	
Warning released temperature	Twrls		115	135	155	

Note: Above values are guaranteed by Design Engineering.
Relationship of above temperature order maintains any time.

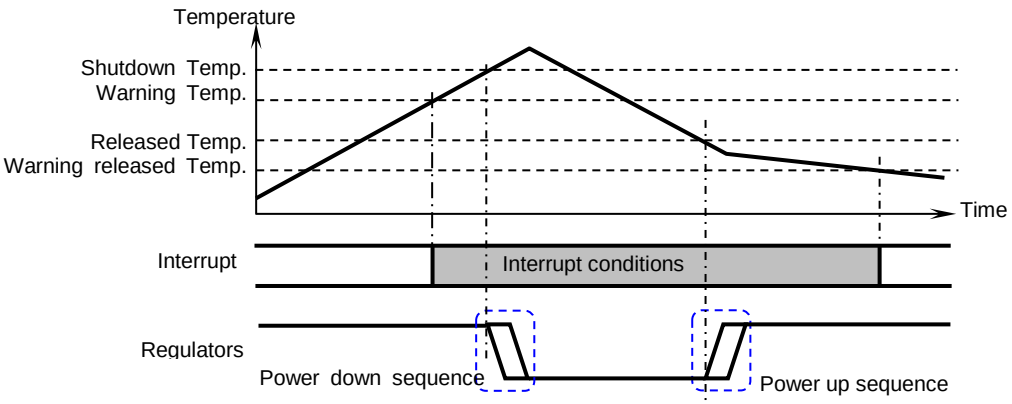


Figure 4-53 Thermal shutdown function

4.13.2. Register

The temperature setting of both detect and release can be changed. The shutdown temperature is fixed at 180°C (TYP)

- Temperature setting
  The below registers are secured registers. Enter “key” code, before entering this request. (Refer to section 4.2.3.)

  - Address (SENTMP): 1EH

A5	A4	A3	A2	A1	A0
0	1	1	1	1	0

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
WARREL (1:0)		THREL (1:0)		WARDET (1:0)		-	-

■ Setting contents

WARDET (1:0)		Warning temp.
D3	D2	
0	0	170°C
0	1	160°C *
1	0	150°C
1	1	140°C

* Default setting

THREL (1:0)		Shutdown release
D5	D4	
0	0	155°C
0	1	145°C *
1	0	135°C
1	1	125°C

* Default setting

WARREL (1:0)		Warning release
D7	D6	
0	0	155°C
0	1	145°C
1	0	135°C *
1	1	125°C

* Default setting

4.14. Monitoring Function

The PMIC has monitoring functions.
The analog monitoring function is indicated internal analog voltages. The digital monitoring function is monitoring digital output pins.

4.14.1. Internal analog voltage monitoring

The PMIC has an analog monitoring function and outputs the regulator level of the PMIC or internal analog voltages with using operational amplifier. A MCU can read these analog voltages through its ADC. Setting register controls output and channel.

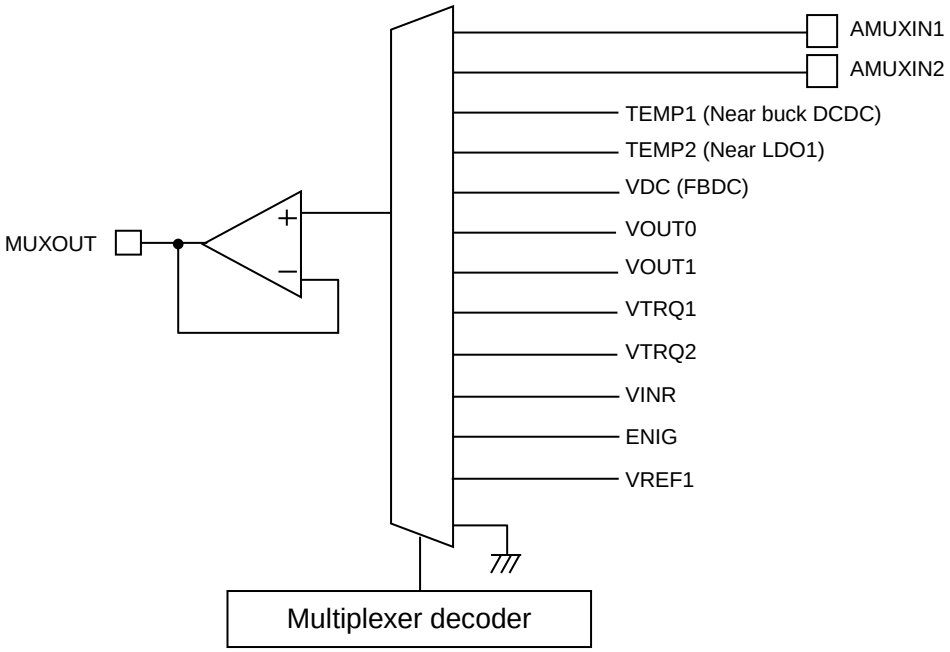


Figure 4-54 Diagram of analog monitoring

4.14.2. Digital output monitoring

The PMIC has a digital monitoring function and compares with output and control signal of digital output buffer. If differentiation is detected, the PMIC makes INTOUT assert low.
The objective outputs are EXCNT1/2, SUSP, RSTB and BKCNT pins. INTOUT pin isn't monitored. For checking the operation of INTOUT, set the "DUMMY" bit of the interrupt.
EXCNT1/2, SUSP and BKCNT monitoring are started after 2µs each changed, RSTB monitoring is started after 100µs.

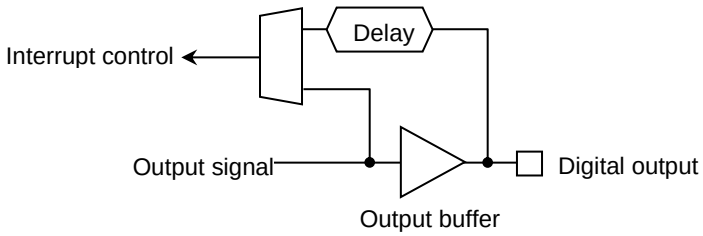


Figure 4-55 Diagram of digital monitoring

4.14.3. Register

The operation setting for monitoring function is described in this section.

- Signal select
  - Address (MUXCNT): 18H

A5	A4	A3	A2	A1	A0
0	1	1	0	0	0

  - Register

D7	D6	D5	D4	D3	D2	D1	D0
-	MUXCNT	-	-	MUXSEL (3:0)			

  - Setting contents

This bit controls on/off control for the analog monitoring

Register name		Control content	Setting	
			1	0
MUXCNT	D6	On/Off control	On	Off *

* Default setting

These bits control the output channel. The analog monitoring outputs 0V in the GND level. And when the analog monitoring selects AMUXIN1/2 and over VOUT1 is input to AMUXIN1/2, MUXOUT outputs VOUT1-0.2V.

MUXSEL (3:0)				Monitoring name
D3	D2	D1	D0	
0	0	0	0	GND level*
0	0	0	1	VINR
0	0	1	0	ENIG
0	0	1	1	FBDC
0	1	0	0	VOUT0
0	1	0	1	VOUT1
0	1	1	0	VTRQ1
0	1	1	1	VTRQ2
1	0	0	0	VREF1
1	0	0	1	TEMP1 (Near Buck DCDC)
1	0	1	0	TEMP2 (Near LDO1)
1	0	1	1	AMUXIN1
1	1	0	0	AMUXIN2
1	1	0	1	GND level
1	1	1	0	GND level
1	1	1	1	GND level

* Default setting

4.14.4. Electrical characteristics

- Input current

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Input current	Ilmux1/2	AMUXIN1/2	-	-	2.0	µA

◆ Output voltage (4.9V ≤ VOUT1 ≤ 5.1V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Output voltage	Xinr	Selected VINR (6.6V ≤ VINR ≤ 28.0V)	0.097	0.10	0.103	Times
	XENIG	Selected ENIG (6.6V ≤ ENIG ≤ 28.0V)	0.097	0.10	0.103	
		Selected ENIG (0V ≤ ENIG ≤ 6.6V), VOUT1 ≥ 4.9V	ENIG/10 -0.02	ENIG/10	ENIG/10 +0.02	V
	Xdc	Selected FBDC	(VoDC)/2 -0.12	(VoDC)/2	(VoDC)/2 +0.12	
	Xldo0	Selected VOUT0	(VOUT0)/2 -0.17	(VOUT0)/2	(VOUT0)/2 +0.17	
	Xldo1	Selected VOUT1	(VOUT1)/2 -0.04	(VOUT1)/2	(VOUT1)/2 +0.04	
	Xtraq1	Selected VTRQ1	(VOUT1)/2 -0.05	(VOUT1)/2	(VOUT1)/2 +0.05	
	Xtraq2	Selected VTRQ2	(VOUT1)/2 -0.04	(VOUT1)/2	(VOUT1)/2 +0.04	
	Vref	Selected VREF1	1.159	1.20	1.241	
	Votmp1	Selected temperature sensor @25°C (Near buck DCDC)	3.12	3.38	3.65	
	Votmp2	Selected temperature sensor @25°C (Near LDO1)	3.12	3.38	3.65	
Input voltage range	Xin1	Selected AMUXIN1 |MUXOUT-AMUXIN1| ≤ 10mV	0.2	2.5	VOUT1 -0.2	
	Xin2	Selected AMUXIN2 |MUXOUT-AMUXIN2| ≤ 10mV	0.2	2.5	VOUT1 -0.2	
Output stable time	Tstb *	From SPICSB rising, Co=50pF	-	-	40	µs

*: Guaranteed by Design Engineering

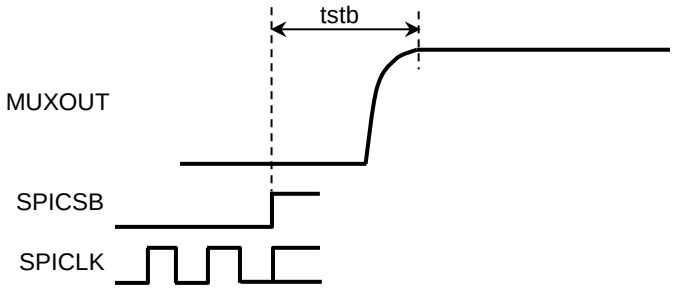


Figure 4-56 Output timing

◆ Output of temperature sensor

The outputs of temperature depend on the junction temperature. For reference, the output temperature characteristic is shown in below figure.
The approximate equation of the output voltage is as follow. And output deviation is ±315mV for every temperature.

Votmp1/2=3.618-0.01*T (V) “T”: Junction temperature

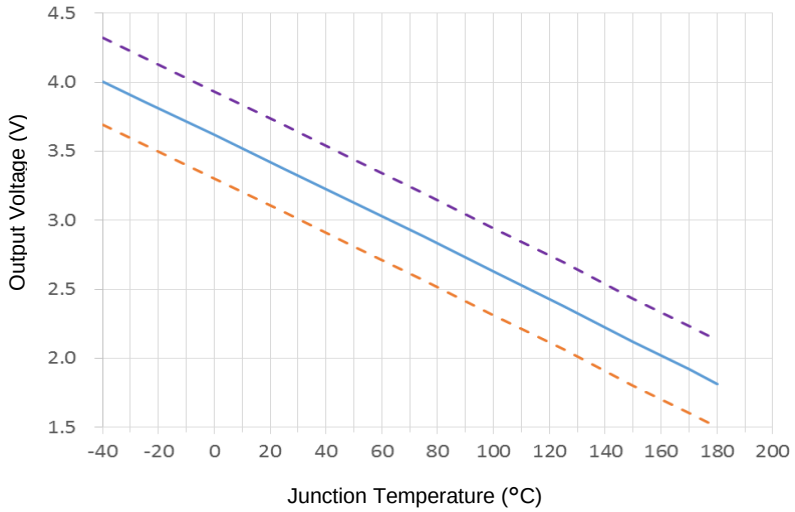
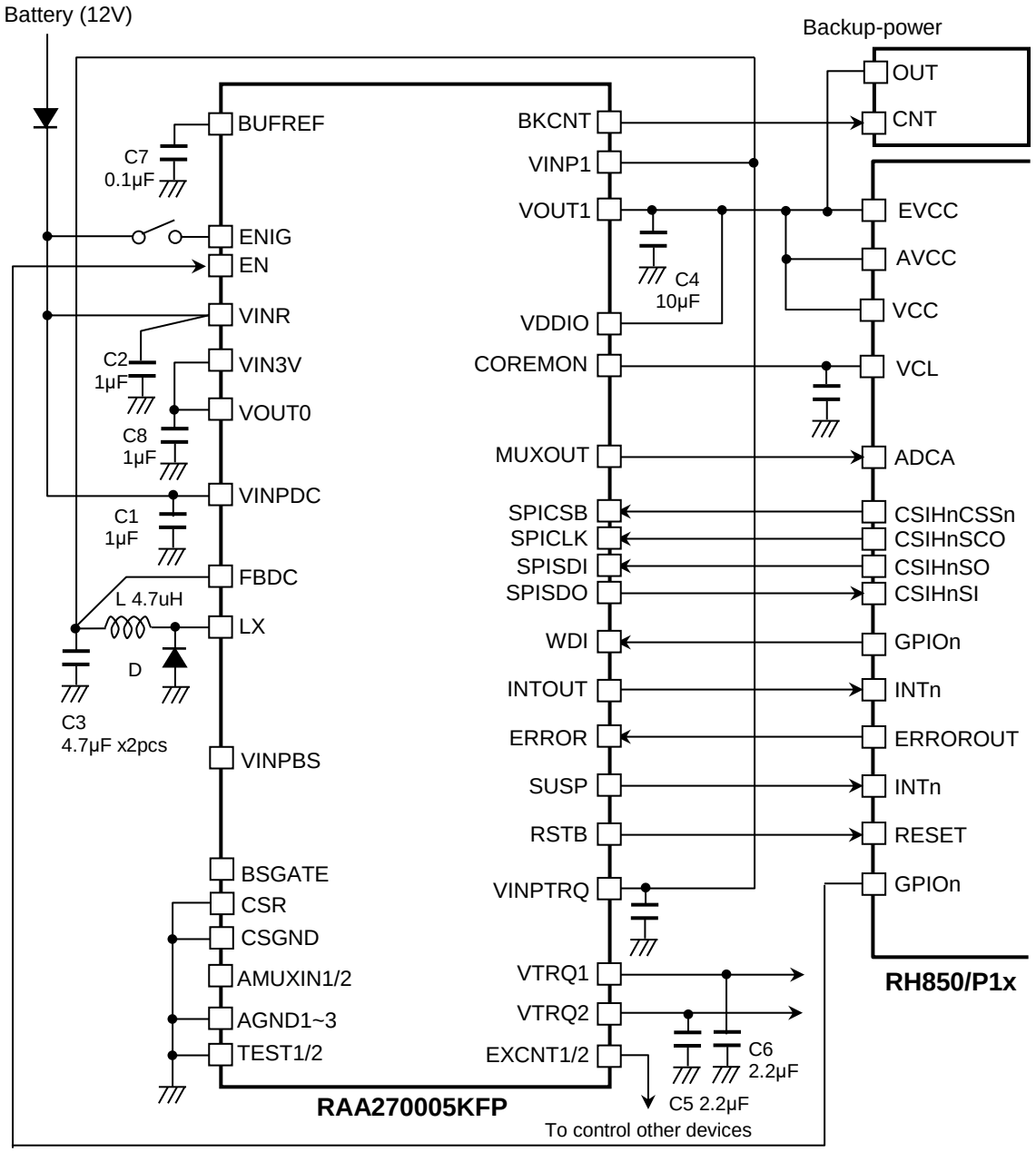


Figure 4-57 Output of temperature sensor

5. Application Example

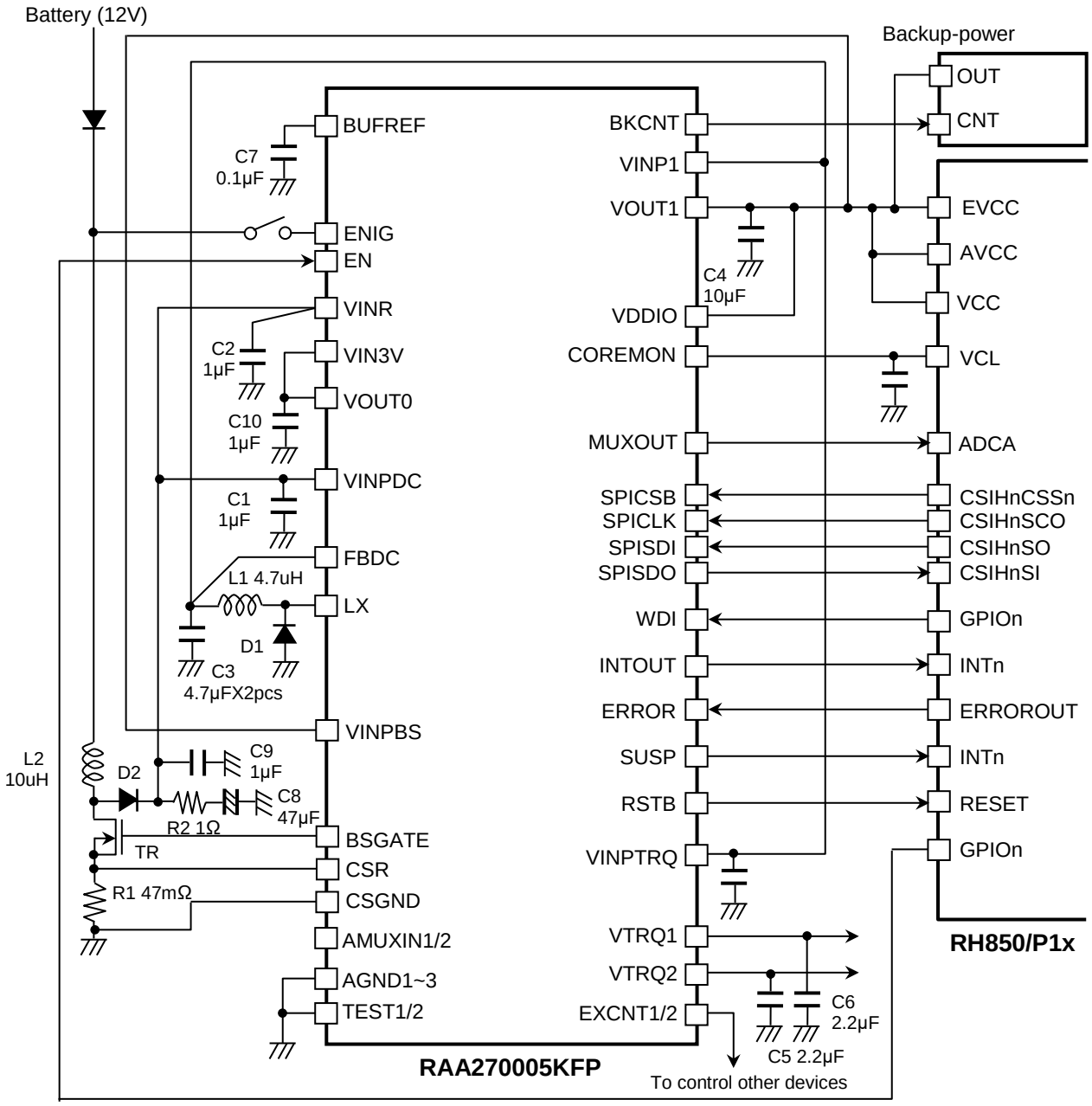
Below figures show typical application diagrams which contain elements around the PMIC.



D M1FS4 (SHINDENGEN) L CLF6045T-4R7M or CLF6045NIT-4R7N (TDK)
C1, C2 GCM21BR71H105K (MURATA)
C3 GCM31CR71C475K (MURATA) C4 GCM21BR701J106K (MURATA) C5, C6 GCM21BR71C225K (MURATA)
C7 GCM188R71C104K (MURATA) C8 GCM219R71C105K (MURATA)

Figure 5-1 Applicaiton ciruit example1 (Boost DCDC non-use)

Note: This is a very simplified example of an application. The function must be verified in the real application.



D1 M1FS4 (SHINDENGEN) D2 M1FM3 (SHINDENGEN) or RB068MM-40(ROHM)
L1 CLF6045T-4R7N (TDK) L2 CLF7045T-100M (TDK)
C1, C2, C9 GCM21BR71H105K (MURATA) C3 GCM31CR71C475K (MURATA)
C4 GCM21BR701J106K (MURATA)
C5, C6 GCM21BR71C225K (MURATA) C7 GCM188R71C104K (MURATA)
C8 EMVY500ADA470MF80G (NIPPON CHEMI-CON) C10 GCM219R71C105K (MURATA)
TR RTR030N05 (ROHM)

Figure 5-2 Application circuit example2 (Boost DCDC use)

Note: This is a very simplified example of an application. The function must be verified in the real application.

5.1. Layout guide lines

Important thing to consider the layout is component placement on the PCB. Take care following things for PCB trace design.

- For proper operation and to prevent EMI radiation, the freewheeling diode and inductor have to be placed as close as possible to the PMIC. Also, the output capacitors have to be placed near by the inductor.
- The feedback trace of buck DCDC converter never crosses the inductor, and recommended connection point is near output capacitor
- For buck DCDC converter, GND connection of components is important. GNDs of input capacitor, output capacitor, and freewheeling diode are connected to the same point.
- For LDO, in order to avoid influence of stray resistance on the PCB, output capacitor has to be placed as close as possible to the PMIC.
- If application needs to apply power supply for multi devices, power distribution at output capacitor of each regulator is recommended.
- In order to maximum heat spread performance, the exposed pad on the backside of the package is recommended to make soldering to GND plane.

6. Electrical Characteristics

6.1. Recommended operating condition

Parameter	Symbol	Pin name	MIN	TYP	MAX	Unit
Input voltage	VBAT	VINR, VINPDC	6.6	12.0	18.5	V
LDO power line	VPLDO	VINP1, VINPTRQ	5.8	6.1	6.4	V
Digital I/O power	VDDIO	VDDIO, VINPBS	3.0	5.0	5.5	V
Circuit power line	VIN3V	VIN3V	3.0	3.3	3.6	V

6.2. Electrical characteristics

6.2.1. DC characteristics

◆ **Digital input**

DC characteristics of digital input pins are shown in the below table.

Parameter	Symbol	Pin name	MIN	TYP	MAX	Unit
High level input voltage 1	VIH1	ENIG	2.5	-	-	V
High level input voltage 2	VIH2	Below pin group	VDDIO*0.7	-	-	V
Low level input voltage 1	VIL1	ENIG	-	-	1.0	V
Low level input voltage 2	VIL2	Below pin group	-	-	VDDIO*0.3	V

Pin group: EN, SPICSB, SPICLK, SPISDI, WDI and ERROR

◆ **Digital output**

DC characteristics of digital output pins are shown in the below table.

Parameter	Symbol	Pin name	MIN	TYP	MAX	Unit
High level output voltage 1	VOH1	Below pin group, IoH=2mA	VDDIO*0.8	-	-	V
High level output voltage 2	VOH2	BKCNT, IoH=1mA	VIN3V*0.8	-	-	V
High level output voltage 3	VOH3	SPISDO, IoH=5mA	VDDIO*0.8	-	-	V
Low level output voltage 1	VOL1	Below pin group, IoL=-2mA	-	-	VDDIO*0.2	V
Low level output voltage 2	VOL2	BKCNT, IoL=-1mA	-	-	VIN3V*0.2	V
Low level output voltage 3	VOL3	SPISDO, IoL=-5mA	-	-	VDDIO*0.2	V
Low level output voltage 4	VOL4	RSTB, IoL=-0.1mA	-	-	0.4	V

Pin group: INTOUT, SUSP and EXCNT1/2

◆ **Pull up/down resistance**

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Pull up resistor 1	Rpu	SPICSB	76	100	127	kΩ
Pull up resistor 2	Rpurs	RSTB	2.6	3.3	4.2	kΩ
Pull down resistor 1	RpdIG	ENIG	390	-	-	kΩ
Pull down resistor 2	Rpd	Below pin group	76	100	127	kΩ

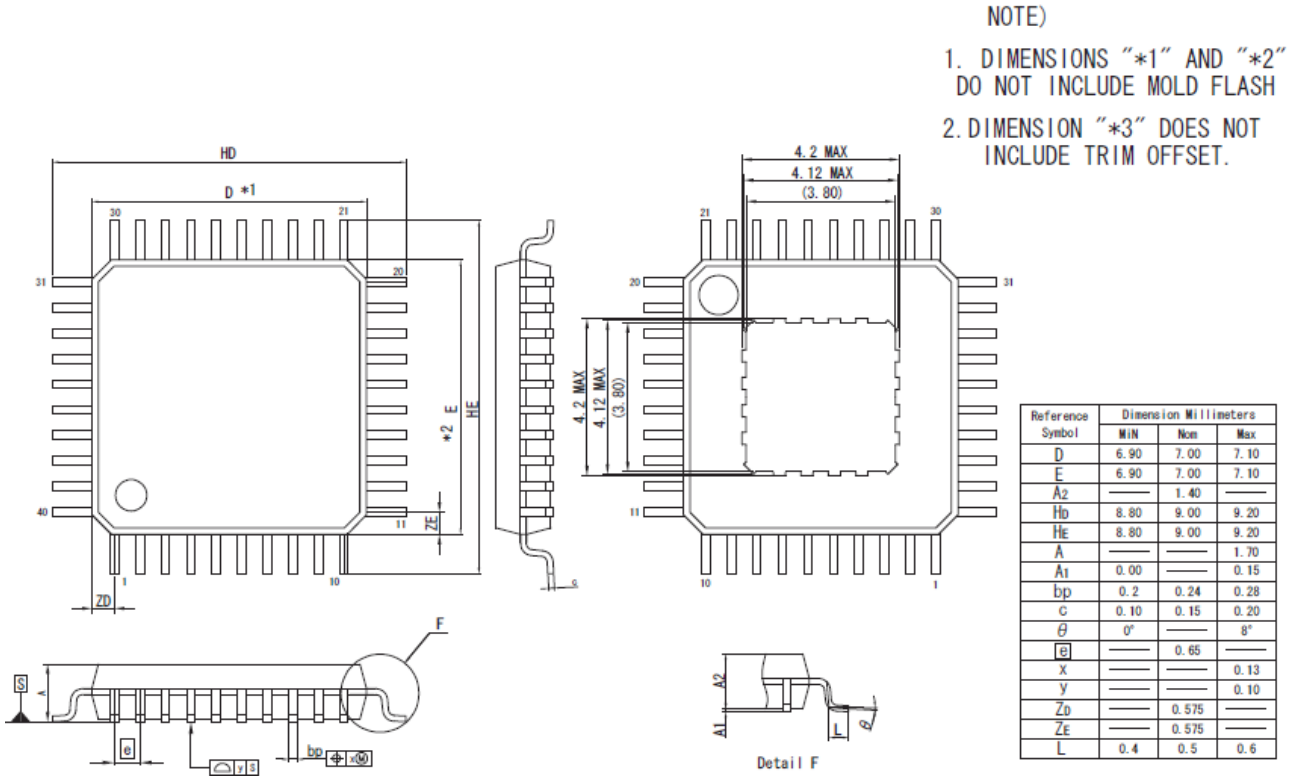
Pin group: EN, SPICLK, SPISDI, WDI and ERROR

◆ **Operating current (Non-load current on each regulator)**

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Stand-by current	Ioff	ENIG=0, EN=0, -40 ≤ Tj ≤ 85°C	-	5.0	10	μA
Operating current 1	Idd1*	ENIG=1 or EN=1	-	2.4	4.5	mA
Operating current 2	Idd2*	Idd1 + Tracker + Analog monitor	-	5.4	14	mA
Operating current 3	Idd3*	Idd2 + Boost DCDC	-	-	15	mA

* Except the external diode leakage current

7. Package Information



Reference Symbol	Dimension Millimeters		
	MIN	Nom	Max
D	6.90	7.00	7.10
E	6.90	7.00	7.10
A_2	—	1.40	—
H_D	8.80	9.00	9.20
H_E	8.80	9.00	9.20
A	—	—	1.70
A_1	0.00	—	0.15
bp	0.2	0.24	0.28
c	0.10	0.15	0.20
θ	0°	—	8°
e	—	0.65	—
x	—	—	0.13
y	—	—	0.10
Z_D	—	0.575	—
Z_E	—	0.575	—
L	0.4	0.5	0.6

Figure 7-1 Package

Revision History	RAA270005KFP Data Sheet

Rev.	Date	Description	
		Page	Summary
1.00	Apr. 2018	-	Initial

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