OPTIREG™ PMIC TLF30681QVS01

Power management IC

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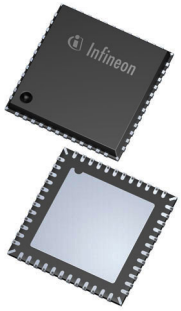
AEC Qualified | RoHS

Features



- High-efficiency step-down pre-regulator for wide input voltage range from 3.7 V to 35 V (40 V limited time) with low overall power loss and fast transient performance
- Suitable for operation with ceramic capacitors
- High-efficiency step-down post-regulator for second output voltage generation
- Step-up post-regulator with 5 V output voltage
- Voltage monitoring for two external voltage rails including enable signals
- 16-bit SPI
- Configurable window watchdog
- Green Product (RoHS compliant)

Potential applications

- Automotive applications
- Advanced Driver Assistance Systems (ADAS)
  - 77 GHz radar ECUs
  - Camera ECUs
- Human Machine Interface (HMI) applications

Product validation

Qualified for automotive applications. Product validation according to AEC-Q100.

Description

The OPTIREG™ PMIC TLF30681QVS01 is a multiple rail Power Management IC (PMIC) for automotive applications, optimized for the use in Advanced Driver Assistance Systems (ADAS). The device consists of a battery connected buck regulator (Buck1) providing 3.3 V to external loads and to two low voltage post-regulators. The first post-regulator (Buck2) provides an output voltage of 1.25 V (output voltage adjustment via SPI in the range of 0.9 V to 1.3 V). The second post-regulator (Boost1) provides an output voltage of 5.0 V and is intended to supply up to two CAN transceivers. The TLF30681QVS01 supports 16-bit SPI communication to a microcontroller. SPI commands can read status information from the device and control features of the power regulators, such as PWM synchronization. The device operates at a nominal switching frequency of 2.2 MHz. The switching frequency is selectable via SPI from 1.8 MHz to 2.5 MHz in steps of 100 kHz. The switching regulators can synchronize to an external clock signal. The TLF30681QVS01 can provide a synchronization signal for other DC/DC regulators in the system. The TLF30681QVS01 provides two voltage monitoring channels with

Description

monitoring inputs and enable outputs. The monitoring channels can be used to control and monitor external LDOs or external DC/DC switching regulators.

Type	Package	Marking
TLF30681QVS01	PG-VQFN-48	TLF30681 S01

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1 Block diagram

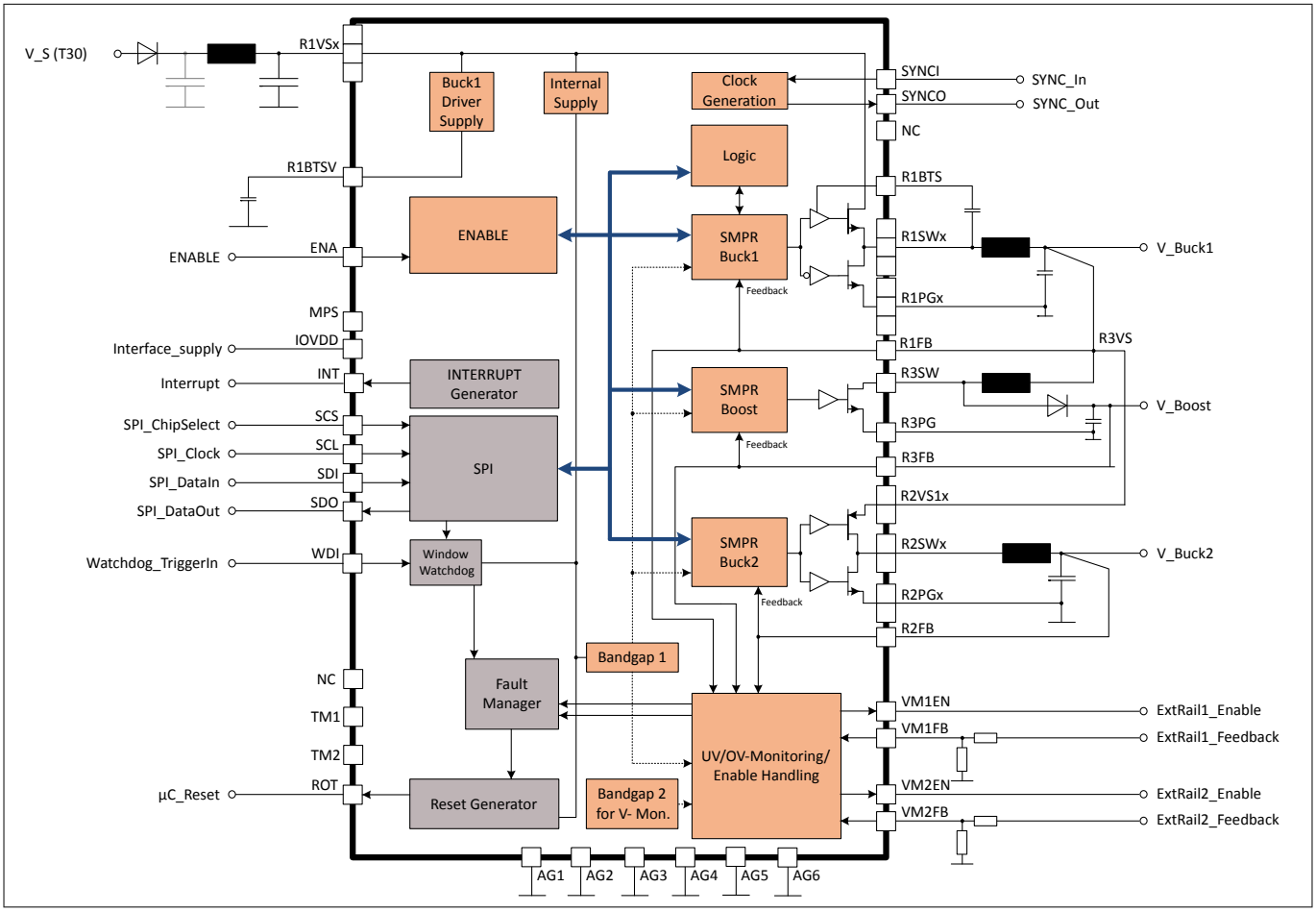


Figure 1 Block diagram

2 Pin configuration

2.1 Pin assignment

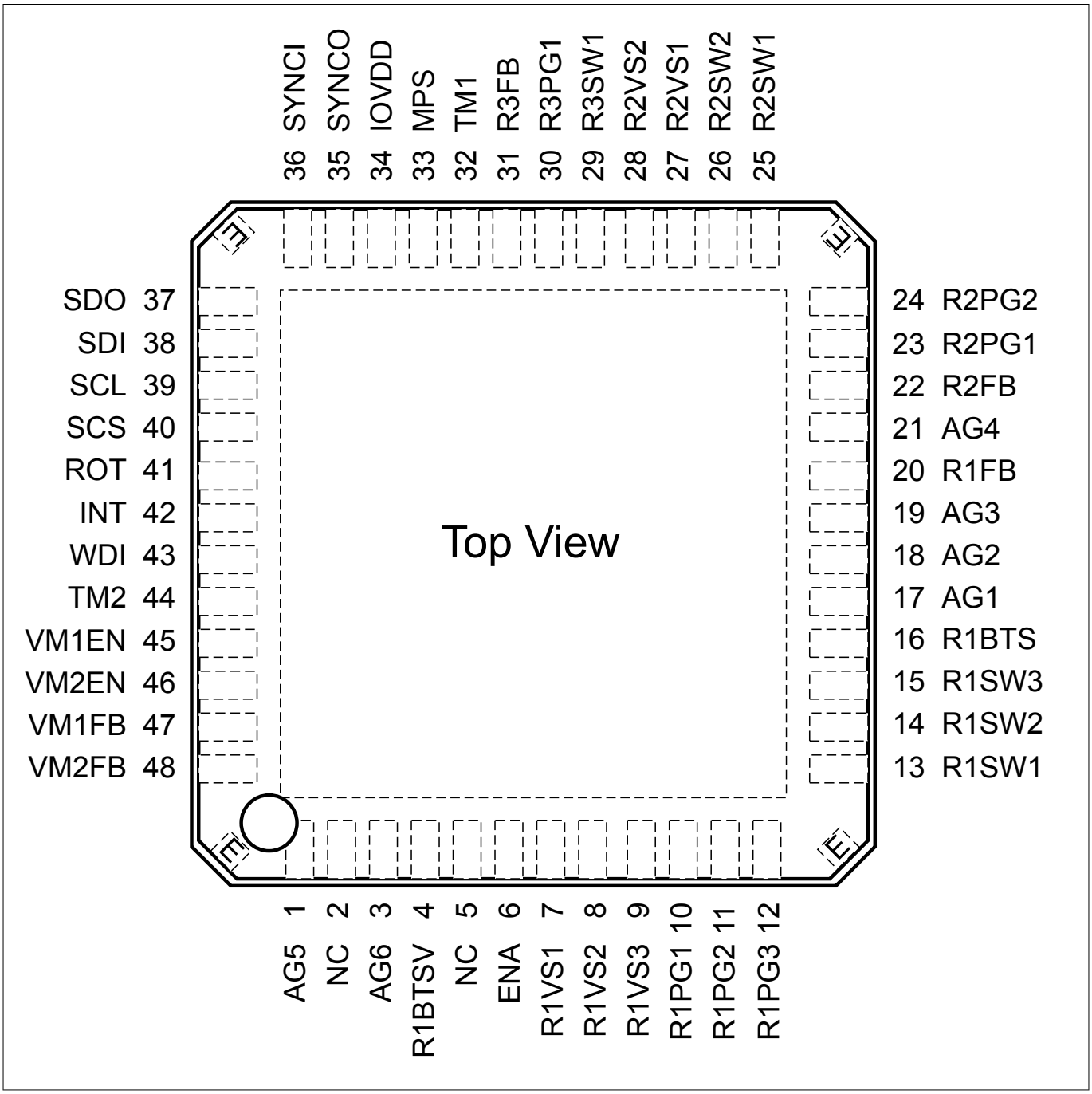


Figure 2 Pin configuration

2.2 Pin definitions and functions PG-VQFN-48

Pin	Symbol	Function
1	AG5	Analog ground, pin 5: Connect this pin directly to ground via a low ohmic and low inductive trace.
2	NC	Not connected: Leave the pin floating in the application.
3	AG6	Analog ground, pin 6: Connect this pin directly to ground via a low ohmic and low inductive trace.
4	R1BTSV	Decoupling of internal supply voltage: Connect a decoupling capacitor between this pin and R1PGx.
5	NC	Not connected: Leave this pin floating in the application.
6	ENA	Enable input: A valid enable condition at this pin enables the device.
7	R1VS1	High voltage regulator supply voltage, pin 1: Connect this pin in parallel with R1VS2 and R1VS3 and then to the supply (battery) voltage via a reverse protection diode. Additionally connect a capacitor between this pin and ground. An EMC filter is recommended.
8	R1VS2	High voltage regulator supply voltage, pin 2: Connect this in parallel with R1VS1 and R1VS3 and then to the supply (battery) voltage via a reverse protection diode. Additionally connect a capacitor between this pin and ground. An EMC filter is recommended.
9	R1VS3	High voltage regulator supply voltage, pin 3: Connect this pin in parallel with R1VS1 and R1VS2 and then to the supply (battery) voltage via a reverse protection diode. Additionally connect a capacitor between this pin and ground. An EMC filter is recommended.
10	R1PG1	High voltage regulator power ground, pin 1: Connect this pin in parallel with R1PG2 and R1PG3 and then to the Buck1 output capacitor ground terminal to ground.
11	R1PG2	High voltage regulator power ground, pin 2: Connect this pin in parallel with R1PG1 and R1PG3 and then to the Buck1 output capacitor ground terminal to ground.
12	R1PG3	High voltage regulator power ground, pin 3: Connect this pin n parallel with R1PG1 and R1PG2 and to the Buck1 output capacitor ground terminal to ground.
13	R1SW1	High voltage regulator power stage output, pin 1: Connect this pin in parallel with R1SW2 and R1SW3 and then to the pre-regulator Buck1 output filter inductor.
14	R1SW2	High voltage regulator power stage output, pin 2: Connect this pin in parallel with R1SW1 and R1SW3 and then to the pre-regulator output filter inductor.

Pin configuration

Pin	Symbol	Function
15	R1SW3	High voltage regulator power stage output, pin 3: Connect this pin in parallel with R1SW1 and R1SW2 and then to the pre-regulator output filter inductor.
16	R1BTS	Bootstrap supply voltage: Connect this pin via the bootstrap capacitor to the R1SWx pins.
17	AG1	Analog ground, pin 1: Connect this pin directly to ground via a low ohmic and low inductive trace.
18	AG2	Analog ground, pin 2: Connect this pin directly to ground via a low ohmic and low inductive trace.
19	AG3	Analog ground, pin 3: Connect this pin directly to ground via a low ohmic and low inductive trace.
20	R1FB	High voltage regulator output voltage feedback: Connect this pin to the Buck1 output capacitor.
21	AG4	Analog ground, pin 4: Connect this pin directly to ground via a low ohmic and low inductive trace.
22	R2FB	Post-regulator output voltage feedback: Connect this pin to the Buck2 output capacitor.
23	R2PG1	Pre-regulator power ground, pin 1: Connect this pin in parallel with R2PG2 and then to the Buck2 output capacitor ground terminal to ground.
24	R2PG2	Pre-regulator power ground, pin 2: Connect this pin in parallel with R2PG1 and then to the Buck2 output capacitor ground terminal to ground.
25	R2SW1	Post-regulator power stage output, pin 1: Connect this pin in parallel with R2SW2 and then to the Buck2 output filter inductor.
26	R2SW2	Post-regulator power stage output, pin 2: Connect this pin in parallel with R2SW1 and then to the Buck2 output filter inductor.
27	R2VS1	Post-regulator supply voltage, pin 1: Connect this pin to the Buck1 output capacitor. In order to compensate for disturbances, add a local bypass capacitor.
28	R2VS2	Post-regulator supply voltage, pin 2: Connect this pin to the Buck1 output capacitor. In order to compensate for disturbances, add a local bypass capacitor.
29	R3SW1	Regulator 3 power stage output, pin 1: Connect this pin to Boost1 inductor and external rectifying diode.
30	R3PG1	Regulator 3 power ground, pin 1: Connect this pin to Boost1 output capacitor ground terminal to ground.
31	R3FB	Regulator 3 output voltage feedback pin: Connect this pin to Boost1 output capacitor.

Pin configuration

Pin	Symbol	Function
32	TM1	Test mode 1: Not for customer use. Leave this pin floating in the application.
33	MPS	Microcontroller programming mode Connect this pin to ground for normal operation in the application. Optionally the pin can be used for microcontroller programming purposes, see ***Application information***.
34	IOVDD	I/O supply voltage: Connect this pin to the I/O supply voltage of the microcontroller. Add a decoupling capacitor.
35	SYNCO	Synchronization output: Optional: Connect this pin to an external switch-mode post-regulator synchronization input. This pin delivers the internal switching frequency signal, either in phase or shifted by 180°, depending on the settings via SPI. The switch-mode post-regulator synchronizes to the rising edge. If this pin is not used, then leave it floating.
36	SYNCI	Synchronization input: Connect this pin to an optional external synchronization signal to synchronize the switching of the internal switch-mode regulators. The feature needs to be enabled via SPI. If the pin is not used, then leave it floating.
37	SDO	Serial peripheral interface, signal data output: SPI signalling port; connect this pin to the SPI port "data input" of the microcontroller to send status information during SPI communication.
38	SDI	Serial peripheral interface, signal data input: SPI signalling port; connect this pin to the SPI port "data input" of the microcontroller to receive status information during SPI communication.
39	SCL	Serial peripheral interface, signal clock input: SPI signalling port; connect this pin to the SPI port "clock" of the microcontroller to clock the device for SPI communication.
40	SCS	Serial peripheral interface, signal chip select: SPI signalling port; connect this pin to the SPI port "chip select" of the microcontroller to address the device for SPI communication.
41	ROT	Reset output: Open drain structure with internal pull up resistor. "Low" indicates a reset event for the microcontroller. Connect this pin to the microcontroller reset input.
42	INT	Interrupt output:

Pin configuration

Pin	Symbol	Function
		Push-pull output. A "low" pulse at this pin indicates an interrupt, and the microcontroller reads the SPI status registers. Connect this pin to a non-maskable interrupt port (NMI) of the microcontroller.
43	WDI	Watchdog input, trigger signal: Connect this pin to the "trigger signal output" of the microcontroller. This pin has an internal pull-down. If this pin is not used, then leave it floating.
44	TM2	Test mode 2: Not for customer use. Connect this pin to GND in the application.
45	VM1EN	Enable signal for external voltage rails 1: Connect this pin to the enable pin of an optional external voltage regulator 1. If the external regulator is not used, then connect this pin to ground.
46	VM2EN	Enable signal for external voltage rails 2: Connect this pin to the enable pin of an optional external voltage regulator 2. If the external regulator is not used, then connect this pin to ground.
47	VM1FB	Input for optional external voltage monitoring rail 1: Connect this pin to an external resistor divider to adjust the overvoltage threshold and the undervoltage threshold of the monitored external voltage generated by the optional external voltage regulator 1. If the optional external regulator is not used, then connect this pin to ground.
48	VM2FB	Input for optional external voltage monitoring rail 2: Connect this pin to an external resistor divider to adjust the overvoltage threshold and the undervoltage threshold of the monitored external voltage generated by the optional external voltage regulator 2. If the optional external regulator is not used, then connect this pin to ground.
Cooling tab	GND	Cooling tab: Internally connected to GND.
–	EP1	Edge pin 1: Keep the area below this pin free of ground or other signals. Do not solder this pin to ground or any other signal. This pin must be kept free of soldering.
–	EP2	Edge pin 2: Keep the area below this pin free of ground or other signals. Do not solder this pin to ground or any other signal. This pin must be kept free of soldering.
–	EP3	Edge pin 3: Keep the area below this pin free of ground or other signals. Do not solder this pin to ground or any other signal. This pin must be kept free of soldering.
–	EP4	Edge pin 4: Keep the area below this pin free of ground or other signals. Do not solder this pin to ground or any other signal. This pin must be kept free of soldering.

3 General product characteristics

3.1 Absolute maximum ratings

Table 1 Absolute maximum ratings[1)]

T_j = -40°C to 150°C; all voltages with respect to ground, positive current flowing into pin, (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Pin							
MPS	V_{MPS}	-0.3	–	6.0	V	–	P_3.1.1
IOVDD	V_{IOVDD}	-0.3	–	6.0	V	–	P_3.1.2
SCS	V_{SCS}	-0.3	–	6.0	V	–	P_3.1.3
SCL	V_{SCL}	-0.3	–	6.0	V	–	P_3.1.4
SDI	V_{SDI}	-0.3	–	6.0	V	–	P_3.1.5
SDO	V_{SDO}	-0.3	–	6.0	V	–	P_3.1.6
WDI	V_{WDI}	-0.3	–	6.0	V	–	P_3.1.7
INT	V_{INT}	-0.3	–	6.0	V	–	P_3.1.10
AG1	V_{AG1}	-0.3	–	0.3	V	–	P_3.1.13
AG2	V_{AG2}	-0.3	–	0.3	V	–	P_3.1.14
AG3	V_{AG3}	-0.3	–	0.3	V	–	P_3.1.15
AG4	V_{AG4}	-0.3	–	0.3	V	–	P_3.1.16
AG5	V_{AG5}	-0.3	–	0.3	V	–	P_3.1.17
AG6	V_{AG6}	-0.3	–	0.3	V	–	P_3.1.18
SYNCI	V_{SYNCI}	-0.3	–	6.0	V	–	P_3.1.19
SYNCO	V_{SYNCO}	-0.3	–	6.0	V	–	P_3.1.20
TM1	V_{TM1}	-0.3	–	6.0	V	–	P_3.1.22
ENA	V_{ENA}	-0.3	–	35	V	2)	P_3.1.23
ENA	I_{ENA}	-5.0	–	–	mA	–	P_3.1.24
R1BTS	V_{R1BTS}	V_{R1SWx} - 0.3	–	V_{R1SWx} + 6.0	V	–	P_3.1.25
R1BTSV	V_{R1BTSV}	-0.3	–	6.0	V	–	P_3.1.26
R1VS1	V_{R1VS1}	-0.3	–	35	V	2)	P_3.1.27
R1VS2	V_{R1VS2}	-0.3	–	35	V	2)	P_3.1.28

1 Not subject to production test, specified by design.
2 Maximum rating is extended to 40 V for an overall time of 7 minutes during the lifetime of the product (load dump requirement).

Table 1 Absolute maximum ratings[1)] (continued)

T_j = -40°C to 150°C; all voltages with respect to ground, positive current flowing into pin, (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
R1VS3	V_{R1VS3}	-0.3	–	35	V	[2)]	P_3.1.29
R1SW1	V_{R1SW1}	-0.3	–	V_{R1VSx} + 2.0	V	–	P_3.1.30
R1SW2	V_{R1SW2}	-0.3	–	V_{R1VSx} + 2.0	V	–	P_3.1.31
R1SW3	V_{R1SW3}	-0.3	–	V_{R1VSx} + 2.0	V	–	P_3.1.32
R1PG1	V_{R1PG1}	-0.3	–	0.3	V	–	P_3.1.33
R1PG2	V_{R1PG2}	-0.3	–	0.3	V	–	P_3.1.34
R1PG3	V_{R1PG3}	-0.3	–	0.3	V	–	P_3.1.35
R1FB	V_{R1FB}	-0.3	–	7.0	V	–	P_3.1.36
R2VS1	V_{R2VS1}	-0.3	–	7.0	V	–	P_3.1.37
R2VS2	V_{R2VS2}	-0.3	–	7.0	V	–	P_3.1.38
R2SW1	V_{R2SW1}	-0.3	–	7.0	V	–	P_3.1.39
R2SW2	V_{R2SW2}	-0.3	–	7.0	V	–	P_3.1.40
R2PG1	V_{R2PG1}	-0.3	–	0.3	V	–	P_3.1.41
R2PG2	V_{R2PG2}	-0.3	–	0.3	V	–	P_3.1.42
R2FB	V_{R2FB}	-0.3	–	7.0	V	–	P_3.1.43
R3SW1	V_{R3SW1}	-0.3	–	7.0	V	–	P_3.1.44
R3PG1	V_{R3PG1}	-0.3	–	0.3	V	–	P_3.1.45
R3FB	V_{R3FB}	-0.3	–	7.0	V	–	P_3.1.46
VM1FB	V_{VM1FB}	-0.3	–	6.0	V	–	P_3.1.47
VM1EN	V_{VM1EN}	-0.3	–	6.0	V	–	P_3.1.48
VM2FB	V_{VM2FB}	-0.3	–	6.0	V	–	P_3.1.49
VM2EN	V_{VM2EN}	-0.3	–	6.0	V	–	P_3.1.50
ROT	V_{ROT}	-0.3	–	6.0	V	–	P_3.1.51
TM2	V_{TM2}	-0.3	–	6.0	V	–	P_3.1.52
Temperatures							
Junction temperature	T_j	-40	–	150	°C	–	P_3.1.53
Storage temperature	T_{stg}	-55	–	150	°C	–	P_4.1.9
ESD susceptibility							

1 Not subject to production test, specified by design.
2 Maximum rating is extended to 40 V for an overall time of 7 minutes during the lifetime of the product (load dump requirement).

Table 1 Absolute maximum ratings[1] (continued)

T_j = -40°C to 150°C; all voltages with respect to ground, positive current flowing into pin, (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
ESD susceptibility all pins	$V_{ESD,HBM}$	-2	–	2	kV	HBM[3]	P_4.1.10
ESD susceptibility all pins	$V_{ESD,CDM}$	-500	–	500	V	CDM[4]	P_4.1.12
ESD susceptibility of corner pins to GND	$V_{ESD,Corner}$	-750	–	750	V	CDM[4]	P_4.1.13

Notes:

1. *Stresses above the ones listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods of time may affect device reliability.*

2. *Integrated protection functions are designed to prevent IC destruction under fault conditions described in the data sheet. Fault conditions are considered as outside the normal operating range. Protection functions are not designed for continuous repetitive operation.*

3.2 Functional range

Table 2 Functional range

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Supply voltage range for normal operation	V_{R1VSx}	5.0	–	35	V	[5]	P_3.2.1
Supply voltage range for reduced operation	V_{R1VSx}	3.7	–	5.0	V	[5][6]	P_4.2.5
Junction Temperature	T_j	-40	–	150	°C	–	P_4.2.9

Note: Within the functional or operating range, the IC operates as described in the circuit description. The electrical characteristics are specified within the conditions given in the electrical characteristics table.

1 Not subject to production test, specified by design.
3 ESD susceptibility, HBM according to ANSI/ESDA/JEDEC JS001 (1.5k Ω, 100 pF).
4 ESD susceptibility, Charged Device Model "CDM" according JEDEC JESD22-C101.
5 When first powered up, a proper startup of the device can only be ensured by applying minimum 6 V at pins R1VSx for at least 2 ms. The device may start at even lower voltages.
6 The current capability of Buck1 is reduced to limit the current stress in the device.

3.3 Thermal resistance

Table 3 Thermal resistance[7)]

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Junction to case	R_{thJC}	–	–	12.2	K/W	–	P_4.3.1
Junction to soldering point (pin)	R_{thJSP}	20.1	–	22.1	K/W	JEDEC 2s2p, measured to pin 1, 3, 17, 18, 19, 21	P_3.3.1
Junction to soldering point (pin)	R_{thJSP}	34.9	–	37.6	K/W	JEDEC 1s0p, measured to pin 1, 3, 17, 18, 19, 21	P_3.3.2
Junction to soldering point (soldering pad)	R_{thJSP}	11.0	–	14.7	K/W	JEDEC 2s2p	P_3.3.3
Junction to soldering point (soldering pad)	R_{thJSP}	13.1	–	18.0	K/W	JEDEC 1s0p	P_4.3.2
Junction to ambient	R_{thJA}	–	37	–	K/W	[8)]	P_4.3.3

*Note: This thermal data was generated in accordance with JEDEC JESD51 standards. For more information visit **www.jedec.org**.*

7 Not subject to production test, specified by design.

8 Specified R_{thJA} value is according to JEDEC JESD51-2,-5,-7 at natural convection on FR4 2s2p board; the product (chip and package) was simulated on a 76.2 × 114.3 × 1.5 mm^3 board with two inner copper layers (2 × 70 µm Cu, 2 × 35 µm Cu). Where applicable, a thermal via array next to the package contacted the first inner copper layer.

3.4 Quiescent current

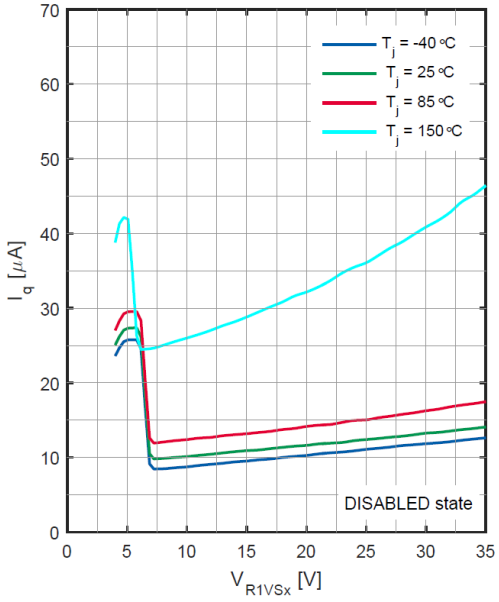
Table 4 Quiescent current

T_j = -40°C to 150°C; V_{R1VSx} = 9 V to 25 V; unless otherwise specified

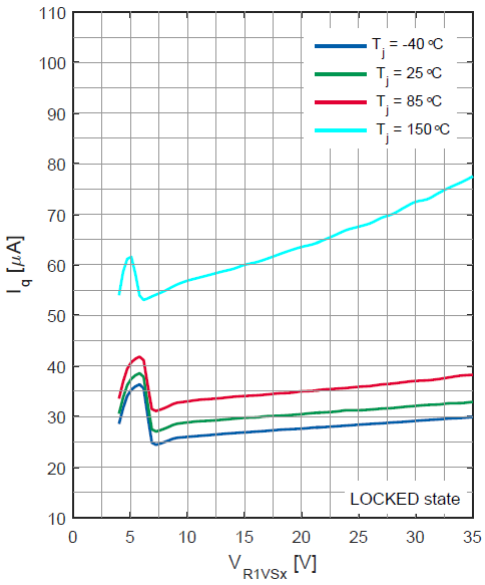
Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
ACTIVE state	$I_{q,OP}$	–	–	20	mA	$T_j \leq 85°C$; $9 V \leq V_{R1VSx} \leq 25 V$; no load, watchdog disabled	P_3.4.1
DISABLED state	$I_{q,DIS}$	–	13	17.5	µA	$T_j \leq 85°C$; $9 V \leq V_{R1VSx} \leq 25 V$	P_3.4.2
DISABLED state	$I_{q,DIS}$	–	11	13.5	µA	$T_j = 25°C$; $V_{R1VSx} = 13.5 V$	P_3.4.3
FAULT state	$I_{q,FLT}$	–	1	2	mA	$T_j \leq 85°C$; $9 V \leq V_{R1VSx} \leq 25 V$	P_3.4.4
LOCKED state	$I_{q,LCK}$	–	35	50	µA	$T_j \leq 85°C$; $9 V \leq V_{R1VSx} \leq 25 V$	P_3.4.5

3.5 Typical performance characteristics quiescent current

DISABLED state - quiescent current I_q versus supply voltage V_{R1VSx}



LOCKED state - quiescent current I_q versus supply voltage V_{R1VSx}



4 Power converters and power management

4.1 High voltage step-down regulator Buck1

4.1.1 Functional description Buck1

The high-voltage step-down regulator Buck1 converts the battery voltage R1VSx to the Buck1 voltage.

A synchronous, current-mode-controlled buck converter with internal power switches is integrated for this purpose. The output rail VBuck1 can be used as direct supply rail as well as pre-regulated rail for post-regulators.

An integrated driver circuit supplied by an external boot-strap capacitor drives the N-/N-MOS power stage. The integrated dead-time optimization prevents cross-conduction, minimizes dead-time and increases system efficiency. An internal voltage divider sets the output voltage. Internal compensation allows for fast loop performance across a wide range of output capacitance. No external tuning of the loop is required. The device supports ceramic capacitors as well as electrolytic capacitors. For detailed information on the selection of the external power stage components, such as the inductor and the filter capacitors for input and output, see ***Application information***.

The converter offers various configuration options:

- Switching frequency selectable via SPI
- Synchronization of the switching frequency to other integrated converters as well as to an external synchronization signal
- Protection features that are designed to prevent damage to the converter due to fault conditions, such as:
  - Overcurrent detection
  - Overtemperature detection

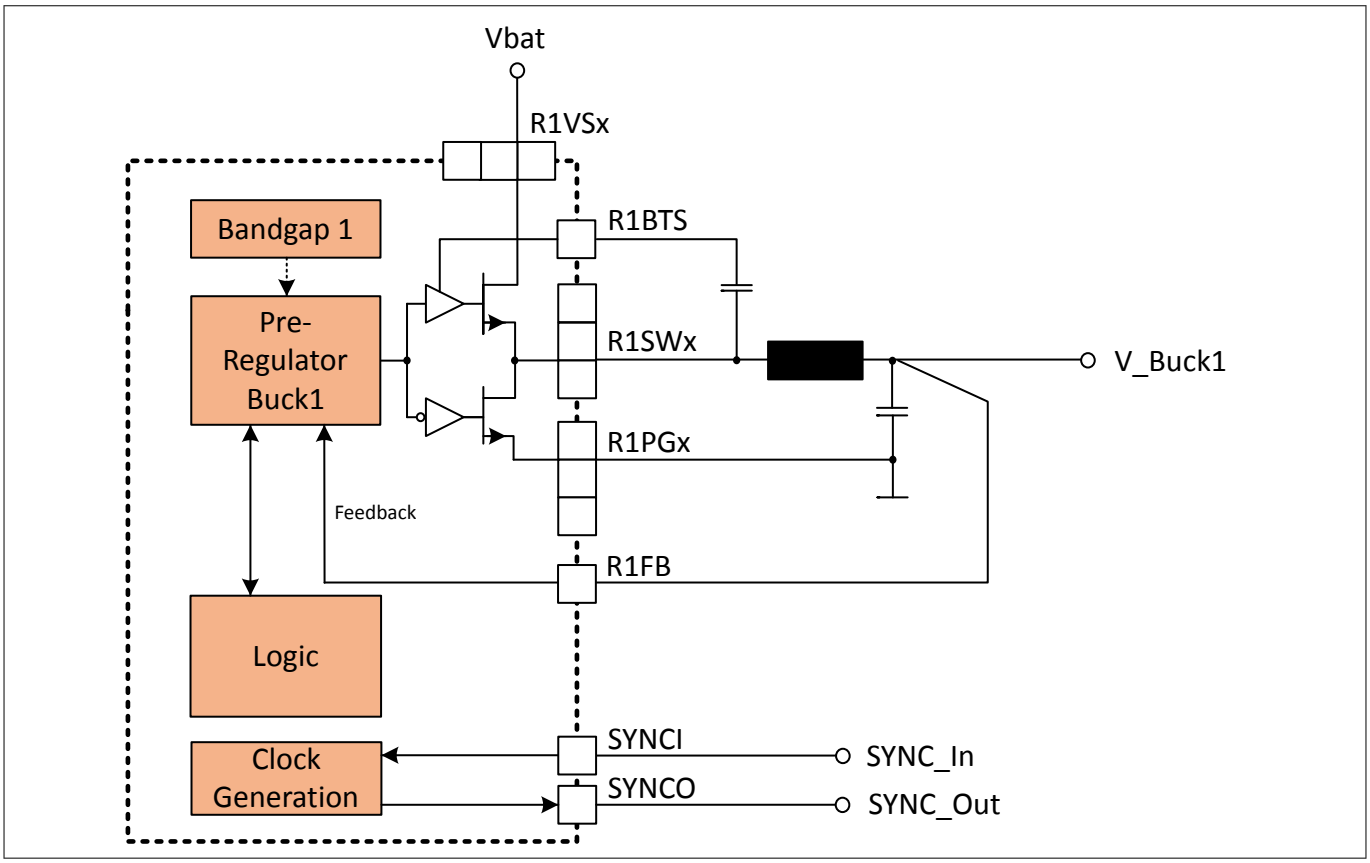


Figure 3 Functional block diagram Buck1

Modulation concept

The converter uses several modulation schemes, depending on the operation mode. It uses a PWM scheme in most of the operating area. It supports synchronization to internal and external clock sources. For light-load and high-line operation it uses pulse-skipping operation. This allows for an improved system efficiency and ensures a minimum turn-on time to ensure correct operation of the switches.

The converter handles the transition between PWM and pulse-skipping automatically, with the need to configure this. The current thresholds and voltage thresholds for this transition depend on the selected power stage components.

Loop compensation

The converter uses a cascaded current-mode, voltage-mode control scheme. An inner loop controls the inductor current, while the external voltage compensation loop regulates the output voltage. The compensation loop can operate with a variety of power stages. For information on the selection of the external components see ***Application information***. The dynamic performance of the system is a function of the power stage components and the internal compensation loop. To achieve optimum performance, follow the design considerations in ***Application information***.

Cycle-by-cycle current limitation

The device features cycle-by-cycle current limitation to protect the switches and external components in case of a fault condition. If the current reaches a defined current threshold, then the peak current monitoring turns off the high-side switch. The device also monitors the current in the low side switch. If the current in the low side switch exceeds the overcurrent threshold at the end of the switching period, then the device does not turn on the high side switch in the subsequent switching period. This allows the device to work as a constant current source.

If the current in the inductor exceeds the overcurrent protection threshold for a defined time t_{R1OCP}, then the device signalizes an overcurrent timeout event through an interrupt (***OCSF1.BUCK1OCW***). It is up to the application to decide how to react in this situation, for example by shutting down the converter.

Overtemperature protection

The converter includes an overtemperature warning and shutdown function to protect the device against damage. If the junction temperature exceeds the overtemperature warning threshold, the device sets an overtemperature warning flag ***OTSF1.BUCK1OTW*** and it generates an interrupt. If the junction temperature continues to rise and exceeds the overtemperature shutdown threshold, then the converter shuts down and generates a thermal shut-down (TSD) event. It sets the ***OTSF0.BUCK1OT*** status flag, which the microcontroller can read after the device enters ACTIVE state again.

OTSTAT0.BUCK1OTW contains the current status of the overtemperature warning. ***OTSF1.BUCK1OTW*** contains the latched information.

Soft start

The integrated soft start feature limits the inrush current and allows for a smooth startup of the converter. The device supports power-sequencing with the other output rails, see ***Power sequencing and soft start***.

4.1.2 Electrical characteristics Buck1

Table 5 Electrical characteristics Buck1

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Input voltage – TLF30681QVS01	V_{R1VSx}	3.7	12	35	V	V_{R1FB} = 3.3 V	P_4.1.2.1
Output voltage – TLF30681QVS01	V_{R1FB}	–	3.3	–	V	–	P_4.1.2.2
Output voltage tolerance	$V_{R1FB,TOL}$	-2	–	+2	%	–	P_4.1.2.9
Maximum output current	I_{R1IOUT}	2.3	–	-	A	5.0 V ≤ V_{R1VSx} ≤ 35 V	P_4.1.2.12
Maximum output current – derated	$I_{R1IOUT,DR}$	1.3	–	–	A	3.7 V ≤V_{R1VSx} < 5.0 V	P_4.1.2.13
High-side switch on-resistance	$R_{DSOn,R1HS}$	–	105	–	mΩ	5.0 V ≤ V_{R1VSx} ≤ 35 V	P_4.1.2.40
High-side switch on-resistance derated	$R_{DSOn,R1HS,DR}$	–	–	–	mΩ	3.7 V ≤ V_{R1VSx} < 5.0 V	P_4.1.2.41
Low-side switch on-resistance	$R_{DSOn,R1LS}$	–	95	–	mΩ	5.0 V ≤ V_{R1VSx} ≤ 35 V	P_4.1.2.42
Low-side switch on-resistance derated	$R_{DSOn,R1LS,DR}$	–	–	–	mΩ	3.7 V ≤ V_{R1VSx} <5.0 V	P_4.1.2.43
Overcurrent protection threshold	I_{R1OCP}	–	–	4.5	A	–	P_4.1.2.22
Overcurrent timeout	t_{R1OCP}	95	100	115	µs	–	P_4.1.2.23
Minimum on-time	t_{R1SWx}	50	58	72	ns	Minimum on-time for internal high side control signal. The actual on-time on the R1SWx pins depends on the application design.	P_4.1.2.25
Overtemperature warning threshold	$T_{j,R1OT,WRN}$	130	145	160	°C	[9)] T_j increasing	P_4.1.2.26
Overtemperature warning threshold	$T_{j,R1OT,WRN}$	120	135	150	°C	[9)] T_j decreasing	P_4.1.2.27
Overtemperature shutdown threshold	$T_{j,R1OT,FLT}$	175	190	205	°C	[9)] T_j increasing	P_4.1.2.28
Overtemperature shutdown threshold	$T_{j,R1OT,FLT}$	165	180	195	°C	[9)] T_j decreasing	P_4.1.2.29

9 Not subject to production test, specified by design.

Table 5 Electrical characteristics Buck1 (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

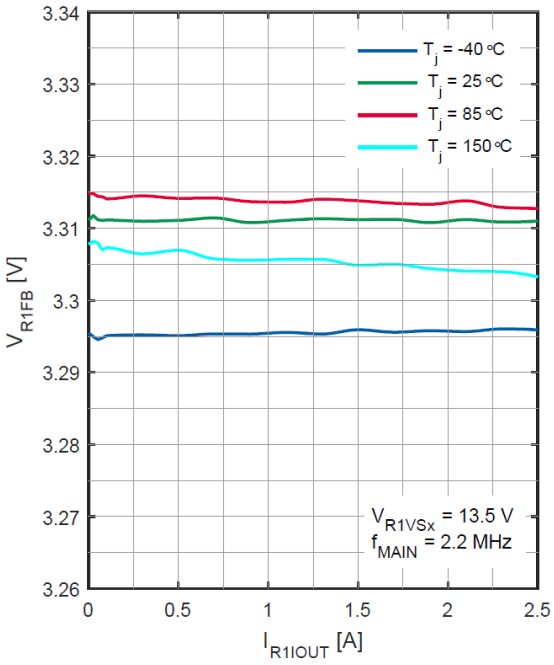
Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Bootstrap capacitor	C_{R1BST}	–	100	–	nF	–	P_4.1.2.30
External power stage components							
Effective inductance	L_{R1}	2.64	3.3	4.0	µH	*10)*	P_4.1.2.33
Effective output capacitance	C_{R1}	75	100	240	µF	*10)11)*	P_4.1.2.35
ESR of output capacitance	R_{R1C}	0	5	30	mΩ	–	P_4.1.2.36

10 For additional information on the allowed L, C combinations see ***Application information***.

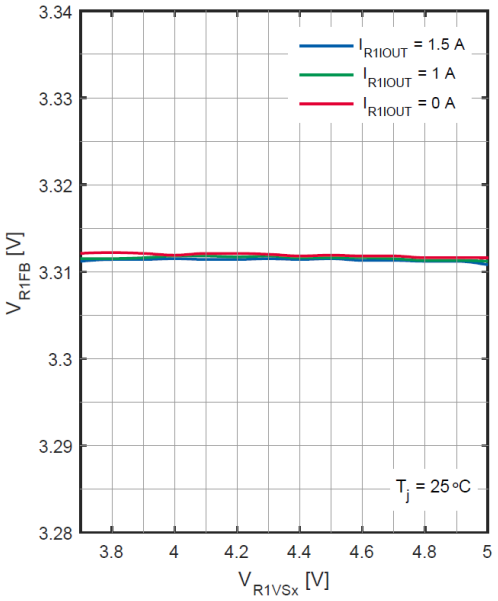
11 Effective capacitance including derating over the temperature range, bias voltage and aging. Electrolytic capacitors as well as ceramic capacitors are supported.

4.1.3 Typical performance characteristics Buck1

Buck1 output voltage V_{R1FB} versus load current I_{R1IOUT}



Buck1 output voltage V_{R1FB} versus supply voltage V_{R1VSx} (drop-out region)



4.2 Post-regulator step-down converter Buck2

4.2.1 Functional description Buck2

The low-voltage step-down regulator Buck2 converts the output voltage of Buck1 to the VBuck2 voltage.

A synchronous, current-mode-controlled buck converter with internal P-/N-MOS power stage is integrated for this purpose. An internal voltage divider sets the output voltage. Internal compensation allows for fast loop performance across a wide range of output capacitance. No external tuning of the loop is required. The design supports ceramic capacitors as well as electrolytic capacitors. For detailed information on the selection of the external power stage components, such as the inductor and the filter capacitors for input and output, see ***Application information***.

Synchronization of the switching frequency with the other integrated converters as well as an external synchronization signal is included. Various protection features, for example overcurrent detection, overtemperature detection and overvoltage detection, are designed to prevent damage to the converter due to fault conditions.

Loop compensation

The integrated loop compensation requires no external components. The dynamic performance of the system is a function of the power stage components and the internal compensation loop. To achieve optimum performance, follow the design considerations in ***Application information***.

Cycle-by-cycle current limitation

The device features cycle-by-cycle current limitation to protect the switches and external components in case of fault condition. If the current reaches a defined threshold, then the peak current monitoring turns off the high-side switch. The device also monitors the current in the low side switch. If the current in the low side switch exceeds the overcurrent threshold at the end of the switching period, then the device does not turn on the high side switch in the subsequent switching period. This allows the device to work as a constant current source.

If this condition persists for a defined time, then the device signalizes an overcurrent timeout event t_{R2OCP} through an interrupt ***OCSF1.BUCK2OCW***. It is up to the application to decide how to react in this situation, for example by shutting down the converter.

Overtemperature protection

The converter includes an overtemperature warning and shutdown function to protect the device against damage. If the junction temperature exceeds the overtemperature warning threshold, then the device sets an overtemperature warning flag ***OTSF1.BUCK2OTW*** and it generates an interrupt. If the junction temperature continues to rise and exceeds the overtemperature shutdown threshold, then the converter shuts down and generates a thermal shut-down (TSD) event. The device sets the ***OTSF0.BUCK2OT*** status flag, which the microcontroller can read after the device enters ACTIVE state again.

OTSTAT0.BUCK2OTW contains the current status of the overtemperature warning. ***OTSF1.BUCK2OTW*** contains the latched information.

Output voltage adjustment via SPI

The device features output voltage adjustment via SPI. Therefore, the microcontroller can adjust the output voltage during ACTIVE state using the registers ***B2VCTRL***, ***B2VCTRLN***. Changes to the output voltage must be limited to 50 mV at a time. This means that the register values of ***B2VCTRL*** and ***B2VCTRLN*** must only be increased or decreased by steps of 1. This is important to avoid false triggering of a Buck2 UV or Buck2 OV event. The settling time of the output voltage for a 50 mV step is 50 µs typically, but it may be longer depending on the output filter selection and the load current condition.

Automatic use detection

The integrated automatic use detection for Buck2 allows the system to tell, whether the application uses Buck2. The device checks the input voltage on the R2VSx pins prior to startup of Buck2. If the pins are connected to the output voltage, then a voltage above the detection threshold is present at the pins and the device assumes that the application requires Buck2. ***HWDECT0.BUCK2AVA*** stores the result of the detection in order to allow the microcontroller to verify correct detection for the specific application and to differentiate the result from a possible fault present on the PCB.

To indicate to the device that the application does not require Buck2, connect the R2VSx pins to R2PGx.

Soft start

The integrated soft start feature limits the inrush current and allows for a smooth startup of the converter. The device supports power-sequencing with the other output rails, see ***Power sequencing and soft start***.

4.2.2 Electrical characteristics Buck2

Table 6 Electrical characteristics Buck2

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Input voltage	V_{R2VSx}	2.9	V_{R1FB}	4.0	V		P_4.2.2.1
Output voltage adjustment range	$V_{R2FB,RANGE}$	0.9	–	1.3	V	–	P_4.2.2.3
Output voltage adjustment step size	$V_{R2FB,STEP}$	–	50	–	mV	$V_{R2FB} = V_{R2FB,RANGE}$	P_4.2.2.4
Output voltage tolerance	$V_{R2FB,TOL}$	-2	–	+2	%	–	P_4.2.2.10
Maximum output current	I_{R2IOUT}	1.0	–	–	A	–	P_4.2.2.12
High-side switch on-resistance	$R_{DSOn,R2HS}$	–	190	–	mΩ	V_{R2VSx} = 3.3 V	P_4.2.2.32
Low-side switch on-resistance	$R_{DSOn,R2LS}$	–	115	–	mΩ	V_{R2VSx} = 3.3 V	P_4.2.2.33
Overcurrent protection threshold	$I_{R2,OCP}$	–	–	3	A	–	P_4.2.2.19
Overcurrent timeout	$t_{R2,OCP}$	95	100	115	µs	–	P_4.2.2.20
Minimum on-time	t_{R2SWx}	64	79	87	ns	Minimum on-time for internal high side control signal. The actual on-time on the R2SWx pins depends on the application design.	P_4.2.2.22
Overtemperature warning threshold	$T_{j,R2OT,WRN}$	130	145	160	°C	12) T_j increasing	P_4.2.2.23
Overtemperature warning threshold	$T_{j,R2OT,WRN}$	120	135	150	°C	12) T_j decreasing	P_4.2.2.24
Overtemperature shutdown threshold	$T_{j,R2OT,FLT}$	175	190	205	°C	12) T_j increasing	P_4.2.2.25
Overtemperature shutdown threshold	$T_{j,R2OT,FLT}$	165	180	195	°C	12) T_j decreasing	P_4.2.2.26
External power stage components							
Effective inductance	L_{R2}	1.2	2.2	4.0	µH	13)	P_4.2.2.28
Effective output capacitance	C_{R2}	52	66	120	µF	13)14)	P_4.2.2.30

12 Not subject to production test, specified by design.
13 For additional information on the allowed L, C combinations see ***Application information***.

Table 6 Electrical characteristics Buck2 (continued)

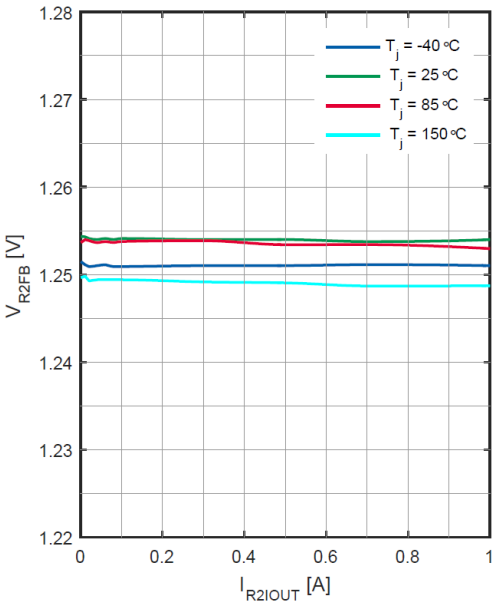
T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
ESR of output capacitance	R_{R2C}	0	5	30	mΩ	–	P_4.2.2.31

14 Effective capacitance including derating over the temperature range, bias voltage and aging. Electrolytic capacitors as well as ceramic capacitors are supported.

4.2.3 Typical performance characteristics Buck2

Buck2 output voltage V_{R2FB} versus
load current I_{R2IOUT}



4.3 Post-regulator step-up converter Boost1

4.3.1 Functional description Boost1

The device integrates a dedicated step-up converter to generate a 5 V output voltage rail from the Buck1 voltage. The converter uses an asynchronous boost topology with internal low-side switch and an external diode.

Synchronization of the switching frequency with the other integrated converters as well as an external synchronization signal is included.

Loop compensation

The integrated loop compensation requires no external components. For information on the selection of the external components see ***Application information***.

Overcurrent protection

The integrated overcurrent protection is designed to protect the internal low-side switch of the boost converter. Due to the nature of the boost topology the boost output rail is not protected against a short circuit directly. However, indirect protection via an undervoltage protection and current limitation of the front-end converter Buck1 is available.

Automatic use detection

The integrated automatic use detection allows the system to tell, whether the application uses Boost1. The device checks the input voltage on the R3FB pin prior to startup of Boost1. If the R3FB pin is connected to the output voltage of Buck1 through the boost inductor and rectifying diode, then a voltage above the detection threshold is present at the pin and the device assumes that the application requires Boost1. ***HWDECT0.BOOST1 AVA*** stores the result of the detection in order to allow the microcontroller to verify correct detection for the specific application and differentiate the result from a possible fault present on the PCB.

To indicate to the device that the application does not require Boost1, connect the R3FB pin to R3PG.

4.3.2 Electrical characteristics Boost1

Table 7 Electrical characteristics Boost1

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

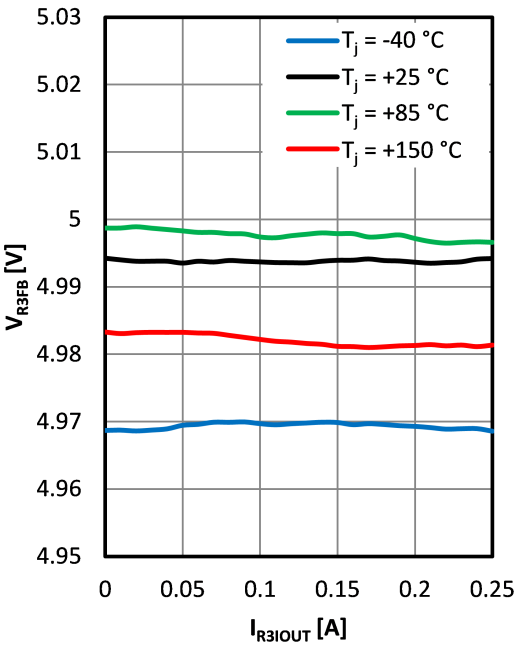
Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Input voltage	V_{R3VS}	2.7	V_{R1FB}	4.5	V	–	P_4.3.2.1
Output voltage	V_{R3FB}	–	5.0	–	V	–	P_4.3.2.2
Output voltage tolerance	$V_{R3FB,TOL}$	-2	–	2	%	–	P_4.3.2.3
Maximum output current	I_{R3IOUT}	250	–	–	mA	–	P_4.3.2.4
Overcurrent detection threshold	$I_{R3,OCP}$	740	820	900	mA	–	P_4.3.2.5
Overcurrent timeout	$t_{R3,OCP}$	170	220	260	µs	–	P_4.3.2.6
External power stage components							
Effective inductance	L_{R3}	3.8	6.8	9.8	µH	*15)*	P_4.3.2.8
Effective output capacitance	C_{R3}	5.5	10	18	µF	*15)16)*	P_4.3.2.10
ESR of output capacitance	R_{R3C}	1	20	50	mΩ	–	P_4.3.2.11

15 For additional information on the allowed L, C combinations see ***Application information***.

16 Effective capacitance including derating over the temperature range, bias voltage and aging. Electrolytic capacitors as well as ceramic capacitors are supported.

4.3.3 Typical performance characteristics Boost1

Boost1 output voltage V_{R3FB} versus
load current I_{R3IOUT}



4.4 Support of external voltage rails

The device supports monitoring of two externally generated voltage rails via voltage monitors. Each voltage monitor consists of an enable pin VMxEN to control the respective regulator and a monitoring input pin VMxFB to monitor the respective voltage rail. The expected voltage on the monitoring input is fixed. If higher voltages is to be monitored, an external voltage divider may be used to reduce the voltage to the expected range.

Automatic use detection

The integrated automatic use detection for each voltage monitor allows the system to tell, whether the application uses it.

If the device can drive the respective enable pin "high", then it device assumes that an external power regulator is connected and that the voltage monitoring is used. ***HWDECT0.VM1AVA*** and ***HWDECT0.VM2AVA*** store the result of the detection, respectively, in order to allow the microcontroller to verify correct detection for the specific application and differentiate the result from a possible fault condition on the PCB.

To indicate to the device that the application does not require a voltage monitor, connect the respective enable pin VMxEN to ground.

4.4.1 Electrical characteristics support of external voltage rails

Table 8 Electrical characteristics external voltage rails

T_j = -40°C to 150°C, V_{R1VSx} = 9 V to 25 V all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Enable signal VMxEN							
Output level – "high"	$V_{VMxEN,high}$	0.7	–	–	V_{IOVDD}	I_{VMxEN} = -7 mA	P_4.4.0.1
Output level – "low"	$V_{VMxEN,low}$	–	–	0.7	V	I_{VMxEN} = -5.5 mA	P_4.4.0.2
Internal pull-down current	I_{VMxEN}	10	–	–	µA	V_{VMxEN} = 0.8 V	P_4.4.0.3
Monitoring signals VMxFB							
Nominal input voltage	$V_{VMxFB,nom}$	–	0.8	–	V	*17)*	P_4.4.0.4
Input pull-up current	I_{VMxFB}	–	100	130	nA	V_{VMxFB} = 0.8 V	P_4.4.0.5

17 For information on the monitoring thresholds please refer to ***Table 14*** in ***Monitoring of external voltage rails***.

5 Central functions

5.1 Supply voltages

The device generates an internal supply voltage from the voltage supplied at the R1VSx pins. This supply voltage R1BTSV power the driver circuit for the power switches of Buck1. R1BTSV cannot be used to supply any external load.

A ceramic capacitor for decoupling must be placed between R1BTSV and the respective ground pin in order to handle the dynamic gate drive current of the power switches.

A supply voltage is required at the IOVDD pin in order to operate the digital outputs of the device, see ***Microcontroller interface supply IOVDD pin***.

5.1.1 Electrical characteristics supply voltages

Table 9 Electrical characteristics supply voltages

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Decoupling capacitor for internal supply							
Internal supply decoupling – connect between R1BTSV and GND	C_{R1BTSV}	0.8	1.0	1.2	µF	–	P_5.1.1

5.2 Enable functionality

The device features an enable functionality which allows powering up the device using the ENA pin. For example, the ENA pin can be connected to the outside of the ECU or to a wake output of a CAN transceiver.

The ENA pin is level-sensitive with a duration-based deglitching. "High" indicates the enabled state. If the voltage at the ENA pin is above the enable detection threshold $V_{ENA,high}$ for a minimum time of $t_{ENA,det}$, then the device considers the enable signal "high", see ***Figure 4***. A signal above the detection threshold for a duration shorter than $t_{ENA,filt}$ is not a valid "high" signal.

If the voltage at the ENA pin is below $V_{ENA,low}$ for a minimum time of $t_{ENA,det}$, then the device considers the enable signal "low". A signal below the detection threshold for a duration shorter than $t_{ENA,filt}$ is not a valid "low" signal.

The device incorporates an enable event detection, where a "low" to "high" transition or a "high" to "low" transition of the enable signal is considered an enable event. Upon detection of an enable event the device generates an interrupt ***SYSSF1-QM.ENA***. Depending on the device state, an enable event can trigger a state transition (see ***State transitions and trigger signals***), for example to power up the device.

An enable event does not disable the device automatically. It is up to the microcontroller to react to the generated interrupt and react accordingly.

VMONSTAT0.ENA stores the state of the enable signal, which the microcontroller can use to determine the current state of the enable signal. This information can be used to differentiate between an enable or disable condition on ECU level.

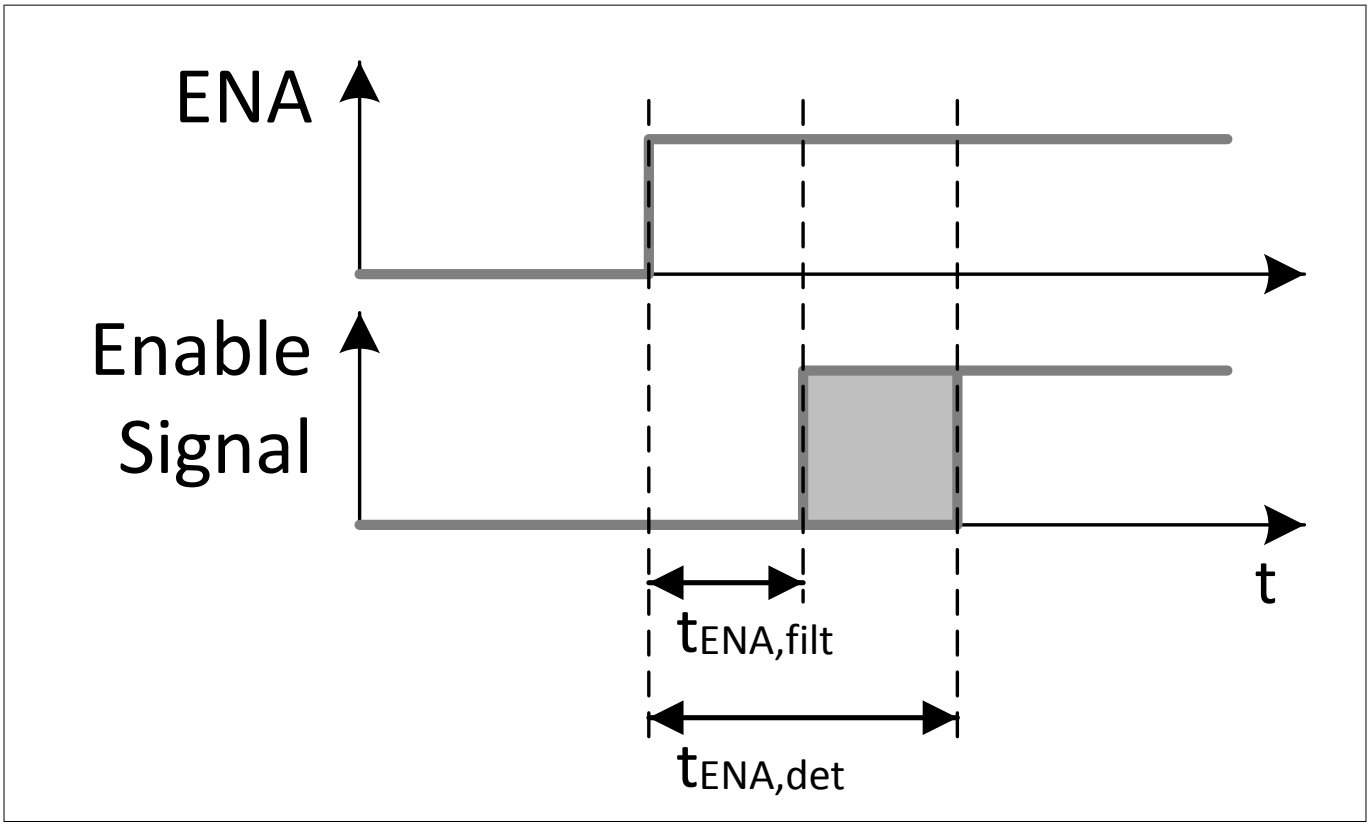


Figure 4 Enable signal – enable event timing

5.2.1 ENA pin configurability

The functionality of the ENA pin can be configured by the microcontroller as edge-triggered or level-sensitive in register ***DEVCFG0.ENA_CONFIG***.

The ENA pin is by default configured to be edge triggered. The device can then only detect an ENA event, if the voltage on the pin rises from "low" to "high".

If the configuration of the ENA pin is set to level-sensitive, then the device automatically re-enters the ACTIVE state from any state if the ENA pin is "high". This means that the device automatically returns to ACTIVE state after a HARD reset event or after entering a LOCKED state with the ENA pin configured to level-sensitive as long as the ENA pin is "high".

The ENA pin must be "low" as a prerequisite for the device to enter DISABLED state from ACTIVE state. If the device enters the DISABLED state on an SPI request to ***DEVCTRL***/***DEVCTRLN***, then the device resets the ***DEVCFG0*** register to the default value. The device can therefore only recognize an ENA event in DISABLED state if the ENA pin has a "low" to "high" transition.

5.2.2 Electrical characteristics enable

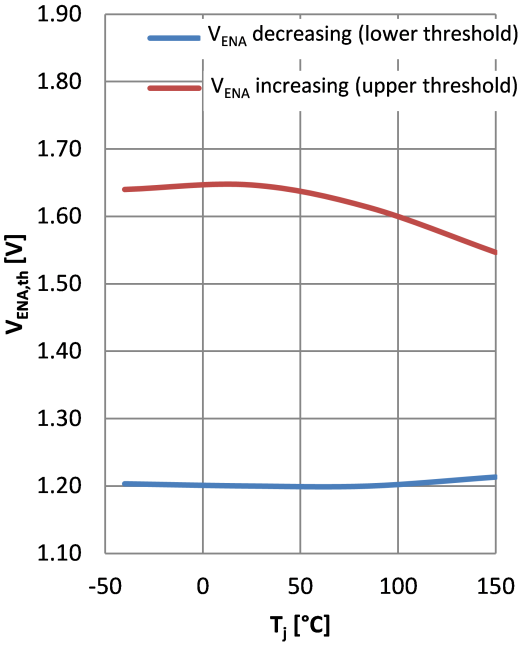
Table 10 Electrical characteristics enable

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Enable signal ENA							
Input voltage "high"	$V_{ENA,high}$	1.30	1.60	2.00	V	V_{ENA} increasing	P_5.2.1
Input voltage "low"	$V_{ENA,low}$	1.00	1.20	1.40	V	V_{ENA} decreasing	P_5.2.2
Input voltage hysteresis	$V_{ENA,hys}$	200	375	–	mV	–	P_5.2.8
Input current "high"	$I_{ENA,high}$	–	3	5	µA	$V_{ENA} \geq 2$ V	P_5.2.4
Input current "low"	$I_{ENA,low}$	–	–	0.1	µA	$V_{ENA} \leq 1$ V	P_5.2.5
Enable signal, filtering time	$t_{ENA,filt}$	–	–	20	µs	–	P_5.2.6
Enable signal, detection time	$t_{ENA,det}$	40	–	–	µs	–	P_5.2.7

5.2.3 Typical performance characteristics enable

ENA pin input voltage thresholds V_{ENA} versus junction temperature T_j



5.3 Power sequencing and soft start

The individual output rails are power sequenced to reduce the inrush current during power-up. The device uses a passive power sequencing method where it enables the individual rails when the preceding rail is within its total operating band, that is between the respective undervoltage and overvoltage fault thresholds.

Sequence of the output rails:

- Buck1
- Buck2, Boost1
- (VM1), (VM2)

Power sequencing is active any time a power rail is enabled or disabled, for example at the transition to ACTIVE.

If the device detects via the automatic use detection that a rail is not active, then power sequencing skips this rail and proceeds with the subsequent rail.

The following conditions must be fulfilled for the power sequence to proceed with the next stage:

- The output voltage on the individual rails must be above the undervoltage threshold
- The rise time must be completed before the next stage is reached

For example, during ramp-up of Buck1 the device waits until its output voltage exceeds the undervoltage threshold and until the rise time t_{Buck1} has elapsed before it initiates the ramping of Buck2 and Boost1. Under normal operating conditions the output voltage on Buck1, Buck2 and Boost1 cross their respective undervoltage thresholds before the rise time has elapsed.

As soon as the device enables a rail, it also enables the corresponding undervoltage monitoring. However, the device only indicates an undervoltage event once, when the voltage rail crosses the undervoltage threshold for the first time. The short-to-ground detection is active and the device uses it as a timeout function for the power sequencing process. If a voltage rail is not valid within the short-to-ground detection time, then the device indicates a fault event. Depending on the configured response to the short-to-ground event (see ***Table 25***), the device may either move into a different state or continue operation and power sequencing.

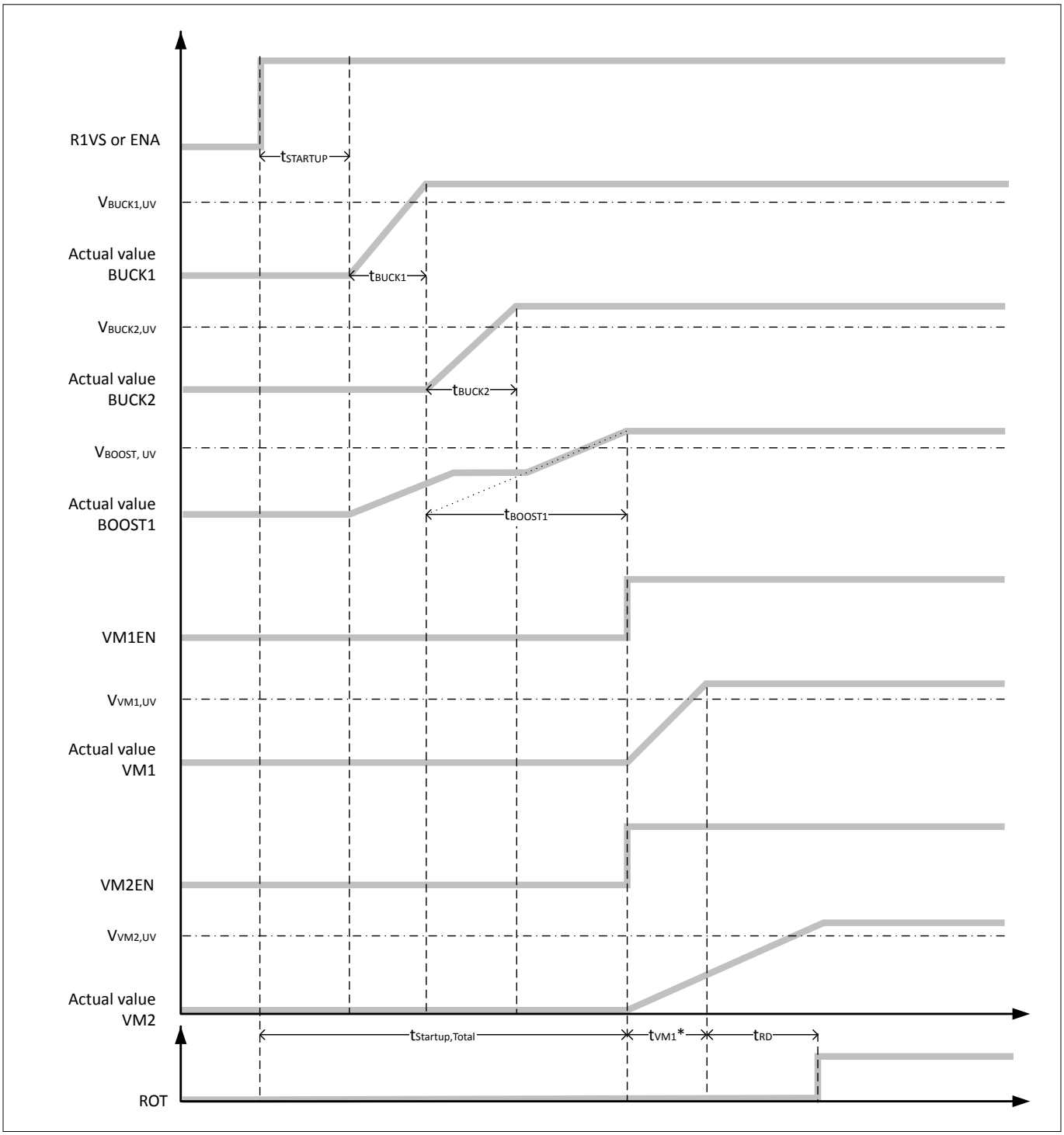


Figure 5 Power sequencing

The device releases the microcontroller reset signal with a configurable delay once the microcontroller supply voltage is within the operating band for a selectable time period ***DEVCFG0.RESDEL***. For generation of the microcontroller reset signal (ROT) see ***Reset generation (ROT signal)***.

The external voltage regulator monitored by VM1 must have a rise time, t_{VM1}, that is shorter than the short-to-ground detection time, $t_{VM1,StG}$, see ***Table 14***.

5.3.1 Electrical characteristics power sequencing and soft start

Table 11 Electrical characteristics power sequencing and soft start

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Internal device startup time	$t_{STARTUP}$	–	300	–	µs	–	P_5.3.1
Output voltage rise time Buck1	t_{BUCK1}	–	640	–	µs	V_{BUCK1} = 3.3 V	P_5.3.2
Output voltage rise time Buck2	t_{BUCK2}	–	320	–	µs	V_{BUCK2} = 1.25 V	P_5.3.4
Output voltage rise time Boost1	t_{BOOST1}	–	640	–	µs	V_{BUCK1} = 3.3 V, V_{BOOST1} = 5.0 V	P_5.3.5

5.4 Frequency generation and clock synchronization

The integrated clock generation and a clock manager generate the switching frequencies for the integrated converters. The device support synchronization to an external clock signal as well as generation of the synchronization signal for external circuits. All all converters support spread spectrum modulation for improved EMC and EMI.

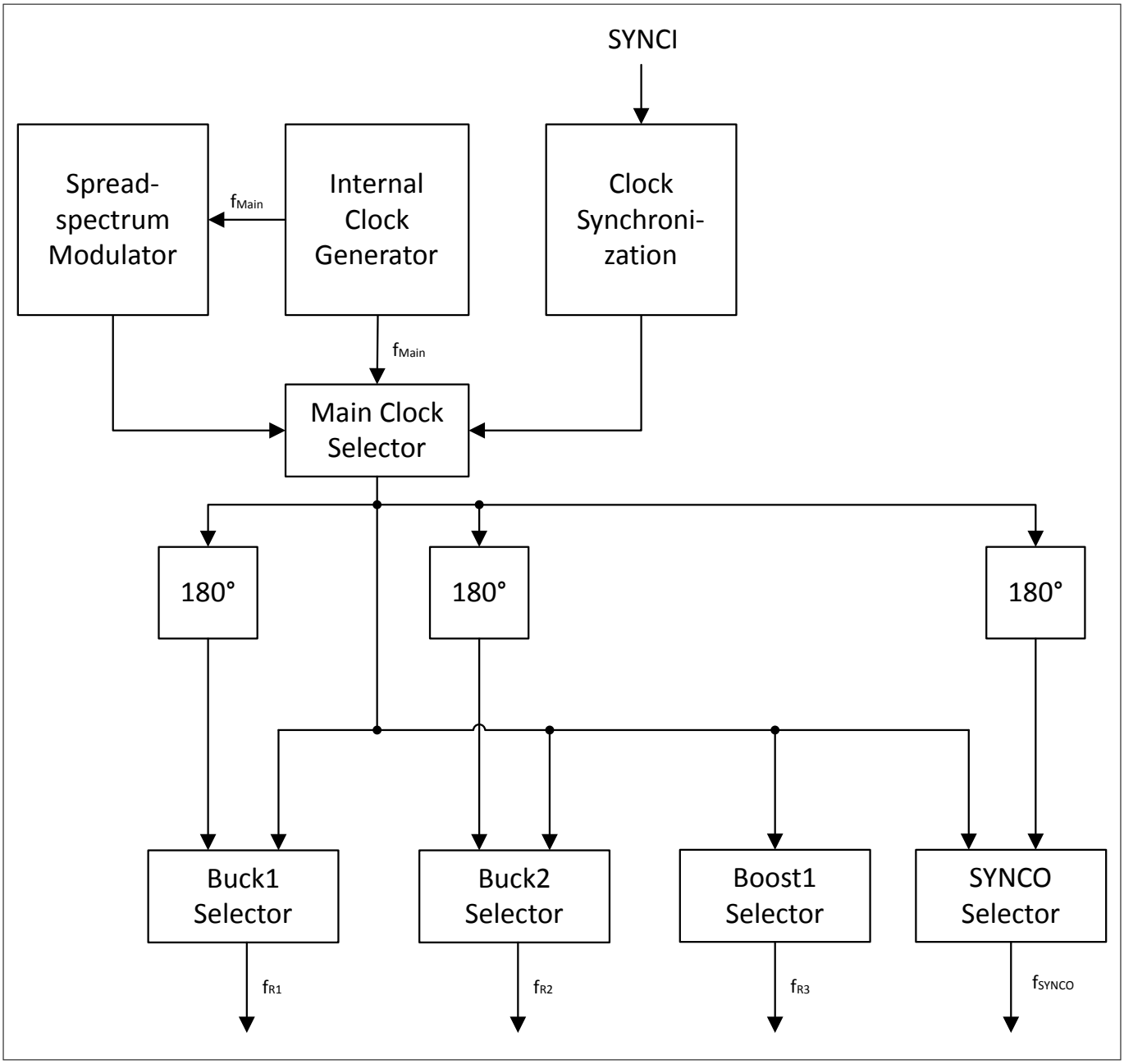


Figure 6 Clock generation and clock manager

Main frequency generation

Figure 6 shows that the internal clock generation uses an internal main frequency to derive the switching frequency for the power converters and the external synchronization signal. ***CLKCFG1*** allows to adjust the main frequency of the system within a given range.

Synchronization

The power converters can be synchronized to an external clock signal (SYNCI) to improve EMC and EMI performance and to reduce cross-talk to the loads.

Table 12 shows the specification of the signal. The clock manager synchronizes the switching frequency to this signal according to the configuration in the SPI registers. The synchronization functionality is disabled by default.

To enable synchronization of the switching frequency, an external reference signal is required at the SYNCI pin and the synchronization functionality must be enabled via SPI. The external clock source must not be removed while the device is running in synchronized mode.

The device supports a dynamic change of the synchronization frequency during synchronization mode with minimal disturbance of the output voltage. It is recommended to keep the same phase and change the switching frequency with the next rising edge of the synchronization signal to minimize the impact on the output voltage. The output voltage settles within a maximum time of 50 µs.

The synchronization output signal SYNCO can be used to synchronize an external switched-mode post-regulator to the device. The output frequency is equal to the switching frequency of Buck1. The synchronization signal has a 50% duty cycle with a selectable phase shift of 0° or 180° with respect to the main clock. The synchronization output is disabled by default. The synchronization output can be enabled via SPI.

CLKCFG0 allows to adjust the phase shift between the individual converters. The phase shift is defined between rising edge of the clock signal and the rising edge of the switch node for the buck converters and the falling edge of the boost converter respectively. Furthermore the converters Buck1 and Buck2, as well as SYNCO can be controlled independently with a phase shift of 0° or 180° with respect to the main clock.

Spread spectrum

The device incorporates spread spectrum in order to improve EMC and EMI performance. Spread spectrum is applied to the main clock source, so it supports all power converters. Spread spectrum is disabled by default. ***CLKCFG0.SSEN*** allows to enable spread spectrum.

5.4.1 Electrical characteristics frequency generation and clock synchronization

Table 12 Electrical characteristics frequency generation and clock synchronization

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Internal clock source							
Frequency	f_{MAIN}	1800	2200	2500	kHz	Switching frequency selectable via SPI	P_5.4.1
Frequency tolerance	$f_{MAIN,tol}$	-10	–	10	%	–	P_5.4.3
Frequency adjustment step size	$f_{MAIN,step}$	–	100	–	kHz	–	P_5.4.4
Synchronization input signal SYNCI[18)]							
Input level "high"	$V_{SYNCI, high}$	0.7	–	–	V_{IOVDD}	V_{SYNCI} increasing	P_5.4.5

Table 12 Electrical characteristics frequency generation and clock synchronization (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

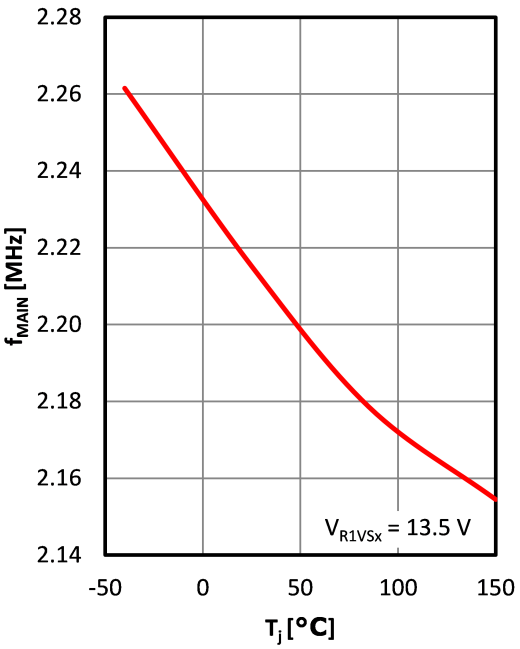
Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Input level "low"	$V_{SYNCI, low}$	–	–	0.8	V	V_{SYNCI} decreasing	P_5.4.6
Input level hysteresis	$V_{SYNCI, hys}$	–	0.06	–	V_{IOVDD}	–	P_5.4.7
Input capacitance	C_{SYNCI}	–	4	15	pF	19)	P_5.4.8
Frequency range	f_{Sync}	1600	2200	2800	kHz	–	P_5.4.9
Duty cycle		40	50	60	%	–	P_5.4.10
Phase delay between SYNCIN and switching edges		–	30	–	ns	–	P_5.4.11
Output voltage settling time	t_{Sync}	–	–	50	µs	–	P_5.4.12
Synchronization output signal SYNCO18)							
Output level "high"	$V_{SYNCO, high}$	0.7	–	–	V_{IOVDD}	I_{IOVDD} = -7 mA	P_5.4.13
Output level "low"	$V_{SYNCO, low}$	–	–	0.7	V	I_{IOVDD} = -5.5 mA	P_5.4.14
Frequency		–	f_{MAIN}	–		–	P_5.4.15
Duty cycle		–	50	–	%	–	P_5.4.16
Spread spectrum modulation							
Maximum modulation variation from $f_{MAIN,Range}$		-7.5	–	7.5	%	5 steps	P_5.4.22
Modulation frequency		–	9	–	kHz	–	P_5.4.23

18 **The voltage levels on this pin are dependent on the IOVDD supply voltage provided (see *Microcontroller interface supply IOVDD pin*).**

19 Not subject to production test, specified by design.

5.4.2 Typical performance characteristics frequency generation

Switching frequency f_{MAIN} versus
junction temperature T_j



5.5 IOVDD - overvoltage detection and undervoltage detection

The IOVDD pin is the supply voltage input for the communication interface towards the microcontroller. The pin can be supplied from one of the voltages generated by the TLF30681QVS01.

The TLF30681QVS01 monitors the voltage on the IOVDD pin. An overvoltage event or an undervoltage event triggers a reset and pulls ROT to GND. As long as no reset event occurs, ROT is "high" (V_{IOVDD}) due to an internal pull-up resistor and follows V_{IOVDD}. ***Figure 7*** shows an example of various events with delay and deglitching times.

In addition the TLF30681QVS01 also features a short-to-ground detection for the IOVDD voltage. If the IOVDD voltage is below the undervoltage threshold for a period longer the short-to-ground detection time, then the device generates a short-to-ground event. A short-to-ground event on IOVDD triggers a hard reset in the device and the ***SYSSF0-QM.IOVDDUV***.

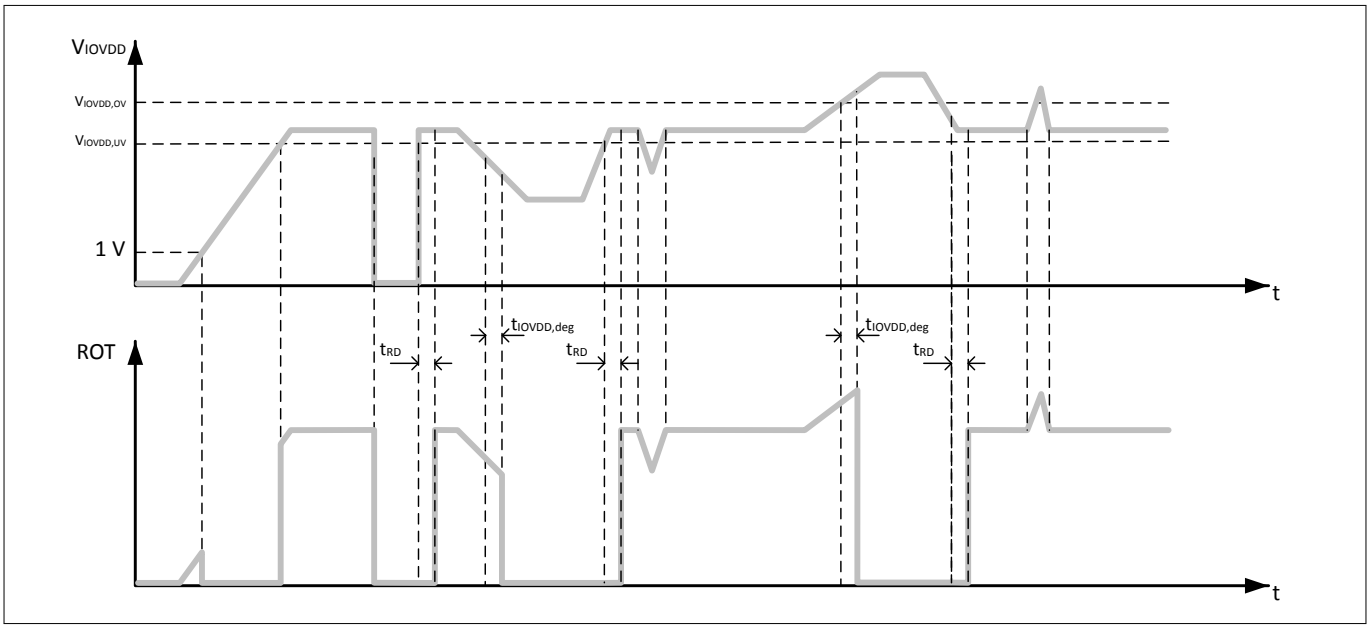


Figure 7 Overvoltage detection and undervoltage detection

5.5.1 Electrical characteristics IOVDD - overvoltage detection and undervoltage detection

Table 13 Electrical characteristics IOVDD - overvoltage detection and undervoltage detection

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
IOVDD - overvoltage threshold	$V_{IOVDD,OV}$	5.5	–	5.8	V	–	P_5.6.1
IOVDD - overvoltage hysteresis	$V_{IOVDD,OV,Hys}$	0.4	–	2.25	%	–	P_5.6.2
IOVDD - undervoltage threshold	$V_{IOVDD,UV}$	2.74	–	2.86	V	–	P_5.6.3

Table 13 Electrical characteristics IOVDD - overvoltage detection and undervoltage detection (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
IOVDD - undervoltage hysteresis	$V_{IOVDD,UV,Hys}$	0.4	–	2.25	%	–	P_5.6.4
Deglitching time	$t_{IOVDD,deg}$	8	–	20	µs	–	P_5.6.5
Short-to-ground detection time	$t_{IOVDD,StG}$	3.6	4.0	4.4	ms	–	P_5.6.6

6 Monitoring functions

The device incorporates various features for using the device as a supply backbone:

- Integrated voltage monitors for the output voltages, see ***Voltage monitoring***
- Integrated window watchdog for supervising microcontroller timing, see ***Window watchdog***

6.1 Voltage monitoring

6.1.1 Monitoring of R1VSx battery supply

If the battery voltage drops below $V_{R1VSx,UV}$, then the undervoltage monitoring feature for R1VSx sets the SPI status flag ***GSF.R1VSxUV***.

6.1.2 Monitoring of output voltages

The voltage monitoring function supervises the voltages on the feedback pins R1FB, R2FB and R3FB of the switched-mode converters with respect to the thresholds for undervoltage and overvoltage, see ***Table 14***.

The device does not detect a signal as a fault event, which crosses the respective thresholds for a time shorter than the deglitching time. When a signal crosses a threshold for a duration longer than the deglitching time, then the device generates an undervoltage event or an overvoltage event. If the voltage is below the undervoltage threshold for a duration longer than the short-to-ground detection time, then the device generates a short-to-ground event in addition. The monitoring also features deep undervoltage detection for Buck1 and Buck2. If the voltage on the feedback pins R1FB or R2FB drops below the deep undervoltage threshold for a duration longer than the deglitching time, then the device generates a short-to-ground event.

Depending on the type of fault, the device executes appropriate according actions, see ***State transitions and trigger signals***.

When the device enables a power rail, it activates the respective voltage monitoring automatically. For information on the behavior during power sequencing see ***Power sequencing and soft start***.

6.1.3 Monitoring of external voltage rails

The device supports monitoring of two external voltage rails on the pins VM1FB, VM2FB. The device compares external voltages using window comparators against predefined thresholds. These thresholds define levels relative to the assumed nominal input voltage, see ***Table 14***. Resistor dividers are to be used to map the output voltage of the respective voltage rail externally.

Signals crossing the thresholds for a time shorter than the deglitching time are not detected as a fault event. When a signal crosses a threshold for a duration longer than the deglitching time, then the device generates an undervoltage event or an overvoltage event. If the voltage is below the undervoltage threshold for a duration longer than the short-to-ground detection time, then the device generates a short-to-ground event in addition.

Depending on the type of fault, the device executes appropriate according actions, see ***State transitions and trigger signals***.

When the device enables a power rail, it activates the respective voltage monitoring automatically. For information on the behavior during power sequencing see ***Power sequencing and soft start***.

If an overvoltage event or a short-to-ground event occurs, then the device shuts down the respective voltage rail to protect the load and the device.

6.1.4 Monitoring of internal supply voltages and bandgaps

The integrated voltage monitoring function monitors internal supply voltages in order to ensure proper operation. If proper operation can not be ensured, then the device reacts accordingly, see ***Table 26***.

The device features two independent voltage references:

- for the voltage regulators
- for voltage monitoring

The device supervises the difference between the voltage references internally.

If the difference exceeds a predefined warning threshold, then the device generates an interrupt and sets one of the following status flags depending on the internal root cause: ***SYSSF1-QM.BGWARN1*** or ***SYSSF1-QM.BGWARN2***. Based on this information the system can be designed to react appropriately.

If the difference exceeds a predefined fault threshold, then the device shuts down and changes into FAULT state, as proper operation of the device can not be ensured. Depending on the internal root cause the device sets ***SYSSF0-QM.BGFLT1*** or ***SYSSF0-QM.BGFLT2***.

6.1.5 Electrical characteristics voltage monitoring

Table 14 Electrical characteristics voltage monitoring

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Input voltage battery supply – (R1VSx-AGx)							
Undervoltage threshold	$V_{R1VSx,UV}$	4.9	5.025	5.15	V	–	P_6.1.5.1
Output voltage Buck1 – (R1FB-AGx)							
Overvoltage threshold	$V_{Buck1,OV}$	+6.0	+8.0	+10	%	Referenced to Buck1 nominal output voltage V_{R1FB}	P_6.1.5.3
Overvoltage hysteresis	$V_{Buck1,OV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.5
Undervoltage threshold	$V_{Buck1,UV}$	-6.0	-8.0	-10	%	Referenced to Buck1 nominal output voltage V_{R1FB}	P_6.1.5.7
Undervoltage hysteresis	$V_{Buck1,UV,Hys}$	0.4	–	2.25	%	–	P_5.2.1.6
Deep undervoltage threshold	$V_{Buck1,DUV}$	-38	-40	-42	%	–	P_6.1.5.9
Deep undervoltage hysteresis	$V_{Buck1,DUV,Hys}$	0.8	–	3.15	%	–	P_6.1.5.10
Deglitching time	$t_{Buck1,deg}$	8	-	20	µs	–	P_6.1.5.11

Table 14 Electrical characteristics voltage monitoring (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Short-to-ground detection time	$t_{Buck1,StG}$	2.7	3.0	3.3	ms	–	P_6.1.5.12
Output voltage Buck2 (R2FB-AGx)							
Overvoltage threshold	$V_{Buck2,OV}$	+6.0	+8.0	+10	%	Referenced to Buck2 nominal output voltage V_{R2FB}	P_6.1.5.16
Overvoltage hysteresis	$V_{Buck2,OV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.18
Undervoltage threshold	$V_{Buck2,UV}$	-6.0	-8.0	-10	%	Referenced to Buck2 nominal output voltage V_{R2FB}	P_6.1.5.20
Undervoltage hysteresis	$V_{Buck2,UV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.22
Deep undervoltage threshold	$V_{Buck2,DUV}$	-38	-40	-42	%	–	P_6.1.5.23
Deep undervoltage hysteresis	$V_{Buck2,DUV,Hys}$	0.8	–	3.15	%	–	P_6.1.5.24
Deglitching time	$t_{Buck2,deg}$	8	-	20	µs	–	P_6.1.5.25
Short-to-ground detection time	$t_{Buck2,StG}$	2.7	3.0	3.3	ms	–	P_6.1.5.26
Output voltage Boost1 – (R3FB-AGx)							
Overvoltage threshold	$V_{Boost1,OV}$	+6.0	+8.0	+10	%	Referenced to Boost1 nominal output voltage V_{R3FB}	P_6.1.5.28
Overvoltage hysteresis	$V_{Boost1,OV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.30
Undervoltage threshold	$V_{Boost1,UV}$	-6.0	-8.0	-10	%	Referenced to Boost1 nominal output voltage V_{R3FB}	P_6.1.5.32
Undervoltage hysteresis	$V_{Boost1,UV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.34
Deglitching time	$t_{Boost1,deg}$	8	-	20	µs	–	P_6.1.5.35
Short-to-ground detection time	$t_{Boost1,StG}$	2.7	3.0	3.3	ms	–	P_6.1.5.36
External voltage monitors VM1 (VM1FB-AGx)							

Table 14 Electrical characteristics voltage monitoring (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Overvoltage threshold	$V_{VM1,OV}$	+6.0	+8.0	+10	%	Referenced to VM1 nominal reference voltage $V_{VM1FB,nom}$	P_6.1.5.38
Overvoltage hysteresis	$V_{VM1,OV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.40
Undervoltage threshold	$V_{VM1,UV}$	-6.0	-8.0	-10	%	Referenced to VM1 nominal reference voltage $V_{VM1FB,nom}$	P_6.1.5.42
Undervoltage hysteresis	$V_{VM1,UV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.44
Deglitching time	$t_{VM1,deg}$	8	-	20	µs	–	P_6.1.5.45
Short-to-ground detection time	$t_{VM1,StG}$	2.7	3.0	3.3	ms	–	P_6.1.5.46
External voltage monitor VM2 (VM2FB-AGx)							
Overvoltage threshold	$V_{VM2,OV}$	+6.0	+8.0	+10	%	Referenced to VM2 nominal reference voltage $V_{VM2FB,nom}$	P_6.1.5.48
Overvoltage hysteresis	$V_{VM2,OV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.50
Undervoltage threshold	$V_{VM2,UV}$	-6.0	-8.0	-10	%	Referenced to VM2 nominal reference voltage $V_{VM2FB,nom}$	P_6.1.5.52
Undervoltage hysteresis	$V_{VM2,UV,Hys}$	0.4	–	2.25	%	–	P_6.1.5.54
Deglitching time	$t_{VM2,deg}$	8	-	20	µs	–	P_6.1.5.55
Short-to-ground detection time	$t_{VM2,StG}$	2.7	3.0	3.3	ms	–	P_6.1.5.56

6.2 Thermal protection

The device incorporates multiple independent temperature sense elements to monitor its temperature, specifically of the high-voltage regulator Buck1 and the post-regulator Buck2. Please refer to the respective sections for more information on the individual blocks.

A third temperature sensor is located in the monitoring block of the device. ***Table 15*** shows the temperature thresholds for the sensor in the monitoring block.

While the device monitors temperature in the individual blocks, it collects the thermal shutdown (TSD) events of these measurements globally. The device sets an appropriate bit in the SPI registers ***OTSF0*** and ***OTSF1*** for each individual warning and fault event.

An overtemperature warning event for any of the three temperature sensors generates an interrupt for the microcontroller.

A thermal shutdown event (TSD) for any of the three sensors triggers a move to the FAULT state. If a thermal shutdown event occurs, then the device extends the fault time to approximately one second (see ***Table 27***) in order to allow the temperature to drop prior to the restart of the device.

6.2.1 Electrical characteristics temperature sensor monitoring block

Table 15 Electrical characteristics temperature sensor monitoring block

V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Overtemperature warning threshold	$T_{j,MONOT,WRN}$	130	145	160	°C	[20] T_j increasing	P_6.2.0.1
Overtemperature warning threshold	$T_{j,MONOT,WRN}$	120	135	150	°C	[20] T_j decreasing	P_6.2.0.2
Overtemperature fault threshold	$T_{j,MONOT,FLT}$	175	190	205	°C	[20] T_j increasing	P_6.2.0.3
Overtemperature fault threshold	$T_{j,MONOT,FLT}$	165	180	195	°C	[20] T_j decreasing	P_6.2.0.4

20 Not subject to production test, specified by design.

7 Microcontroller interface and supervisory functions

This section describes the connections between the device and the microcontroller.

Figure 8 shows that the microcontroller and the device use several signals for communication and for mutual monitoring of correct operation. An SPI configures the device and monitors status information. A dedicated interrupt signal of the device notifies the microcontroller about any interaction required. To ensure safe operation of the microcontroller a watchdog trigger line (WDI) is available. The device can use a reset-output signal (ROT) to reset the microcontroller if required.

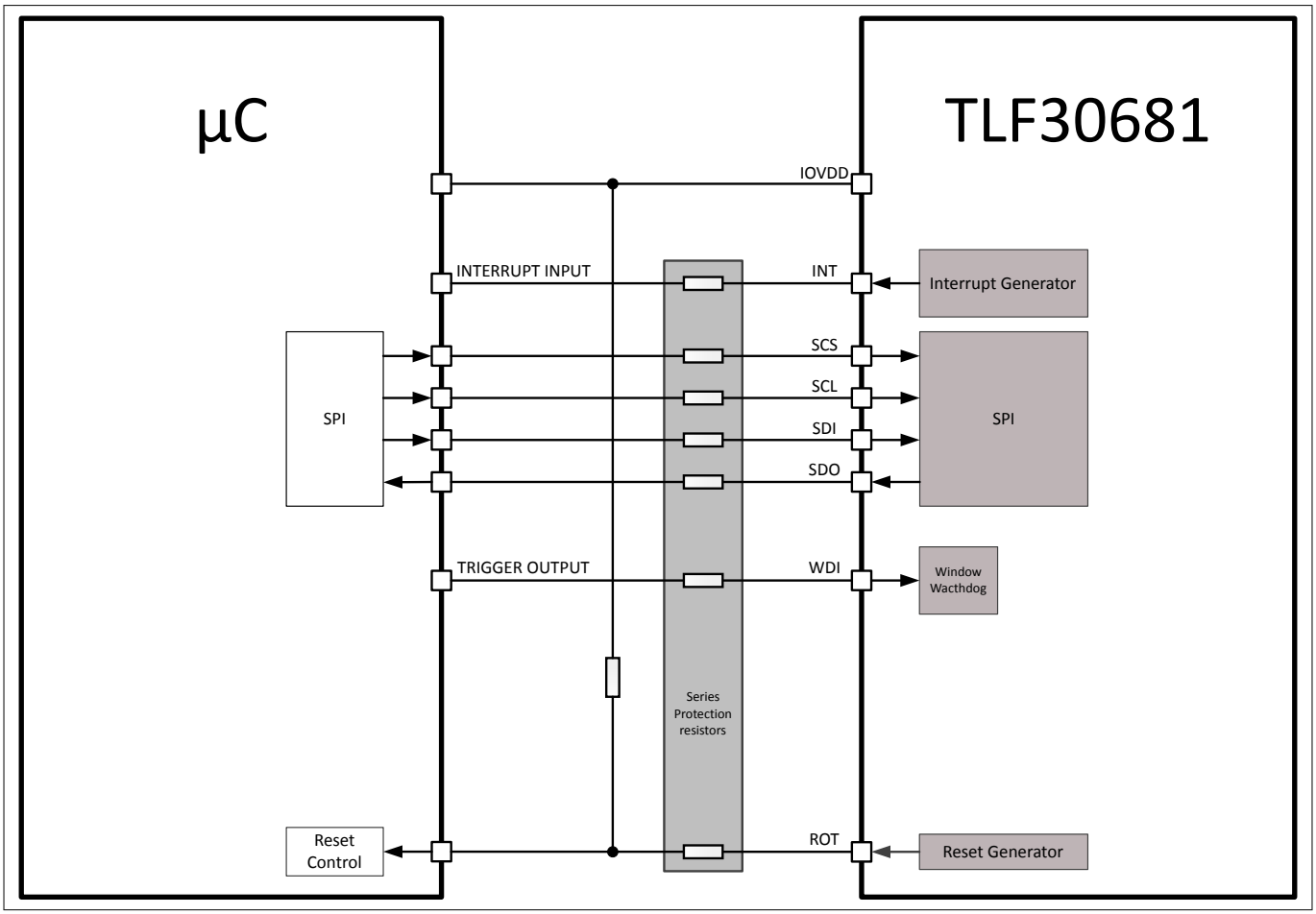


Figure 8 Interface between device and microcontroller

7.1 Microcontroller interface supply IOVDD pin

The device can handle microcontrollers with different IO supply voltages. This is accommodated by a dedicated supply pin (IOVDD) at which the IO supply voltage is externally supplied to the device. This voltage then drives the logic output pins to the microcontroller. It is also used to determine the input thresholds for the input cells. The affected pins are:

- SCS
- SCL
- SDI
- SDO
- INT
- ROT

Microcontroller interface and supervisory functions

- WDI
- SYNCI
- SYNCO

7.1.1 Electrical characteristics microcontroller interface supply

Table 16 Electrical characteristics microcontroller interface supply

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Microcontroller interface							
Supply voltage	V_{IOVDD}	3.0	–	5.5	V	–	P_7.1.1.1
Supply current	I_{IOVDD}	–	2.5	–	mA	V_{IOVDD} = 3.3 V; SDO, SDI and SCL switching at 10 MHz; SYNCI and SYNCO switching at 2.5 MHz; SCS, ROT, INT and WDI are static signals	P_7.1.1.2

7.2 Serial peripheral interface (SPI)

7.2.1 SPI introduction

The serial peripheral interface (SPI) is a synchronous serial data link that operates in full duplex mode. The SDI pin receives data from the microcontroller and the SDO pin transmits data to the microcontroller.

The device communicates in slave mode where the master, for example the microcontroller, provides a clock on the SCL pin and initiates the data frame. The device is addressed via a dedicated chip select line (SCS pin).

Functional description SPI

The data on pin SDI is captured on the falling edge of the SPI clock signal (pin SCL) and shifted on the rising edge of the SPI clock signal. The data on pin SDO is set on the falling edge of SPI clock signal (pin SCL) and shifted on the rising edge of the SPI clock signal. The SPI master is to capture the data on the falling edge of the SPI clock signal.

An SPI command consists of the following parts, see ***Figure 9***:

- command bit CMD
- 6 address bits A0-A5
- 8 data bits D0-D7
- parity bit P

The SPI response for read operations consists of the following parts:

- command bit CMD
- 6 status bits S0-S5
- 8 data bits D0-D7
- parity bit P

For a write operation, the data read on SDI is looped back via SDO.

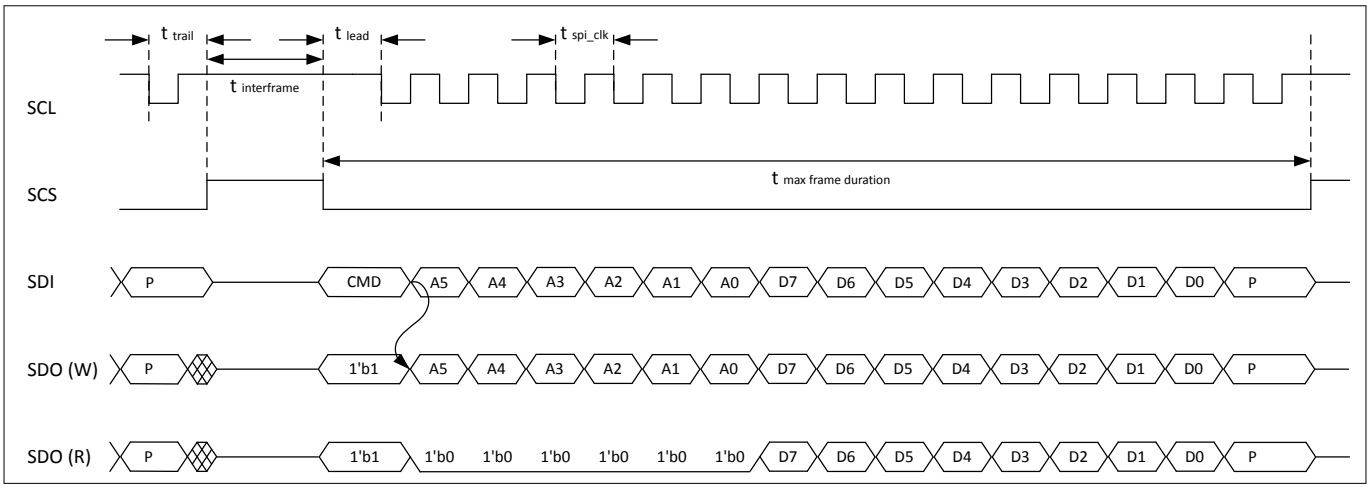


Figure 9 SPI frame format

The command bit in the SPI command is set to 1’b0 for a read and 1’b1 for a write operation. In the reply, the command bit is always set to 1’b1.

The parity bit P is calculated from the 15 data bits of the SPI message consisting of the CMD bit, the 6 address bits and the 8 data bits. The parity bit is set to ‘1’, if the number of ‘1’s in the data bits is odd, that is it is a XOR function of the 15 data bits. The receiver of the SPI message should verify the parity bit prior to processing the payload of the message.

The SPI performs several checks on the communication to ensure proper behavior:

- If a parity fault occurs, then the device ignores the data, sets the SPI status bit ***SPISF.PAR*** and generates an interrupt.
- If a write operation to an invalid address occurs, then the device ignores the data, sets the SPI status ***SPISF.ADDR*** and generates an interrupt.
- If a read operation from an invalid address occurs, then the device reads all data bits as zero and sets the parity bit to a wrong value in order to indicate an incorrect message to the SPI master. In addition the device sets the SPI status bit ***SPISF.ADDR*** and generates an interrupt.
- If a write operation with an incorrect number of SPI clock cycles occurs while SCS is "low", then the device ignores the data, sets the SPI status ***SPISF.LEN*** and generates an interrupt.
- If a read operation with an incorrect number of SPI clock cycles occurs, then the device sets the SPI status ***SPISF.LEN*** and generates an interrupt to indicate an invalid data message to the SPI master. The SDO pin provides the data during this operation. At the end of the message it indicates its correctness.
- If the frame duration exceeds the maximum frame time t_{SPI_fl}, then the device terminates communication by disabling the output driver of the SDO pin. In addition the device sets the SPI status bit ***SPISF.DUR*** and generates an interrupt.

The device initiates interrupts on SPI errors are only after SCS is driven "high" or after a frame timeout occurs.

7.2.2 SPI write access to protected registers

Certain registers are protected against accidental write operations.

Those protected registers are implemented in pairs, where a protected register (for example ***PWDCFG0***) is used to store a configuration request, while an associated read-only register (for example ***RWDCFG0***) is used to store the currently active configuration.

By default, write access to protected registers is disabled. The status of the protection can be checked using ***PROTSTAT.LOCK***. Write access must be enabled using the UNLOCK sequence prior to updating the registers. After completing the register update, the configuration must be activated using the LOCK sequence. This disables the write access to the protected register and copies the data to the read-only registers.

After the LOCK sequence an internal configuration time of maximum of 60 µs must be considered to ensure that the new configuration is applied in the device.

Read access to protected configuration registers is always possible. Read operations invert the data.

The device does not support updating a single protected register. The microcontroller must ensure that all protected registers are configured properly by writing a new value into particular registers and by verifying the content of unchanged registers.

UNLOCK sequence

An UNLOCK sequence consists of four consecutive key bytes (1: AB_H; 2: EF_H; 3: 56_H; 4: 12_H) written into the ***PROTCFG*** register. The respective SPI write operations must be atomic, so that they are not interrupted by an SPI write operation to a different register. Read operations to any register are permitted. The progress of the UNLOCK sequence can be monitored in the ***PROTCFG*** register where the respective key bit is set for each correctly written key byte. If an incorrect UNLOCK sequence occurs due to a wrong key or an SPI write operation to a different address, then the device resets the UNLOCK sequence and clears all key bits. The device sets the ***SPISF.LOCK*** bit and generates an interrupt. The microcontroller must restart the UNLOCK sequence.

LOCK sequence

A LOCK sequence consists of four consecutive key bytes (1: DF_H; 2: 34_H; 3: BE_H; 4: CA_H) written into the ***PROTCFG*** register. The respective SPI write operations must be atomic, so that they are not interrupted by an SPI write operation to a different register. Read operations to any register are permitted. The progress of the LOCK sequence can be monitored in the ***PROTCFG*** register where the respective key bit is set for each correctly written key byte. If an incorrect LOCK sequence occurs due to a wrong key or an SPI write operation to a different address, then the device resets the LOCK sequence and clears all key bits. The device sets the ***SPISF.LOCK*** bit and generates an interrupt. The microcontroller must restart the LOCK sequence.

7.2.3 SPI write initiated state transition request and regulator configuration

State machine transitions and configuration of output rails can be performed with direct write access to dedicated registers. A defined protocol protects the registers from unintended changes.

In order to request a state transition or a change of the configuration of an output rail the request data must be written to two separate, inverted registers (***DEVCTRL*** and ***DEVCTRLN***). The write operation must be atomic, with no other SPI write operation to a different address interrupting the initial write. The data is applied on the rising edge of the CS at the end of the second command.

If an invalid protocol occurs, then the device rejects the request, sets the SPI status flag ***SPISF.DEVCTRL*** and generates an interrupt.

The following conditions lead to invalid requests:

- An SPI write operation to a different address, which interrupts the write operation to ***DEVCTRL*** and ***DEVCTRLN***
- The data in ***DEVCTRL*** and ***DEVCTRLN*** is not consistent

If an invalid state transition request occurs, according to the state machine in Chapter 8, then the device ignores the transition request without generating an interrupt. The device executes the change in configuration of output rails.

7.2.4 Configuration of Buck2 output voltage via SPI

The output voltage of Buck2 can be configured with direct write access to dedicated registers. A specific protocol is used to avoid unwanted changes to the registers.

In order to request a change of the Buck2 output voltage the configuration data must be written to two separate, inverted registers (***B2VCTRL*** and ***B2VCTRLN***). The write operation must be atomic with no other SPI write operation to a different address interrupting the initial write. The data is applied on the rising edge of the CS at the end of the second command.

If an invalid protocol occurs, the device rejects the request, sets the SPI status flag ***SPISF.B2VCTRL*** and generates an interrupt.

The following conditions lead to invalid requests:

- An SPI write operation to a different address, which interrupts the write operation to ***B2VCTRL*** and ***B2VCTRLN***.
- The data in ***B2VCTRL.B2VOUTF*** and ***B2VCTRLN.B2VOUTF*** is not consistent.

If a Buck2 output voltage configuration request is invalid, then the device ignores the request without generating an interrupt.

7.2.5 SPI timing

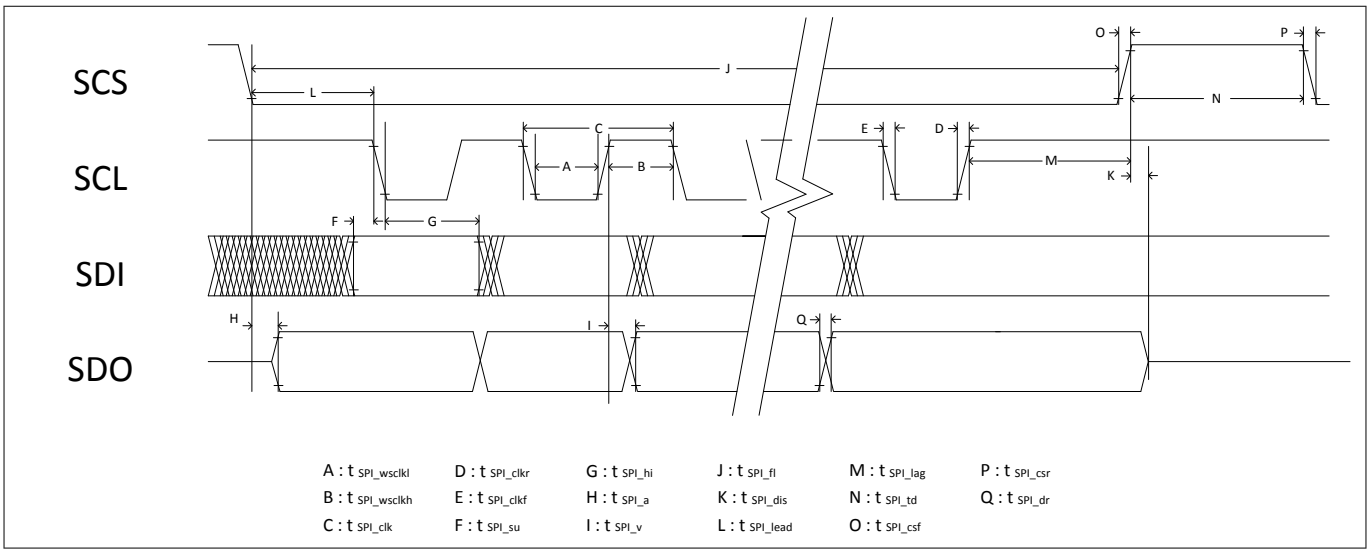


Figure 10 SPI timing

7.2.6 Electrical characteristics SPI

Table 17 Electrical characteristics SPI

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
SPI chip select SCS							
Valid input level "high"	$V_{SCS, high}$	0.7	–	–	V_{IOVDD}	V_{SCS} increasing	P_7.2.5.1
Valid input level "low"	$V_{SCS, low}$	–	–	0.8	V	V_{SCS} decreasing	P_7.2.5.2
Input hysteresis	$V_{SCS, hys}$	–	0.06	–	V_{IOVDD}	–	P_7.2.5.3
Pull-up current	I_{SCS}	-180	-55	–	µA	$V_{IOVDD} \leq 5.0$ V	P_7.2.5.4
Input capacitance	C_{SCS}	–	4	15	pF	21)	P_7.2.5.5
SPI clock SCL							
Valid input level "high"	$V_{SCL, high}$	0.7	–	–	V_{IOVDD}	V_{SCL} increasing	P_7.2.5.6
Valid input level "low"	$V_{SCL, low}$	–	–	0.8	V	V_{SCL} decreasing	P_7.2.5.7
Input hysteresis	$V_{SCL, hys}$	–	0.06	–	V_{IOVDD}	–	P_7.2.5.8
Pull-up current	I_{SCL}	-180	-55	–	µA	$V_{IOVDD} \leq 5.0$ V	P_7.2.5.9
Input capacitance	C_{SCL}	–	4	15	pF	21)	P_7.2.5.10
SPI data input SDI							
Valid input level "high"	$V_{SDI, high}$	0.7	–	–	V_{IOVDD}	V_{SDI} increasing	P_7.2.5.11
Valid input level "low"	$V_{SDI, low}$	–	–	0.8	V	V_{SDI} decreasing	P_7.2.5.12
Input hysteresis	$V_{SDI, hys}$	–	0.06	–	V_{IOVDD}	–	P_7.2.5.13
Pull-down current	I_{SDI}	–	135	330	µA	$V_{SDI} = V_{IOVDD}$	P_7.2.5.14
Input capacitance	C_{SDI}	–	4	15	pF	21)	P_7.2.5.15
SPI data output SDO							
Output level "high"	$V_{SDO, high}$	0.7	–	–	V_{IOVDD}	I_{SDO} = -7 mA	P_7.2.5.16
Output level "low"	$V_{SDO, low}$	–	–	0.7	V	I_{SDO} = -5.5 mA	P_7.2.5.17
Output rise time	$t_{SDO,rise}$	–	–	25	ns	$C_{SDO,Load}$ = 50 pF	P_7.2.5.18
Output fall time	$t_{SDO,fall}$	–	–	25	ns	$C_{SDO,Load}$ = 50 pF	P_7.2.5.19
Output tristate capacitance	$C_{SDO,tri}$	–	4	15	pF	21)	P_7.2.5.20
Output tristate leakage	$I_{SDO,tri}$	-10	–	10	µA	–	P_7.2.5.21

21 Not subject to production test, specified by design.

7.2.7 Electrical characteristics SPI timing

Table 18 Electrical characteristics SPI timing

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
CLK_SPI operating frequency	f_{SPI_clk}	–	–	10	MHz	–	P_7.2.5.22
CLK signal duty cycle	D_{SCL}	45	50	55	%	–	P_7.2.5.23
CLK_SPI "high" time	t_{SPI_wsclkh}	45	–	–	ns	–	P_7.2.5.24
CLK_SPI "low" time	t_{SPI_wsclkl}	45	–	–	ns	–	P_7.2.5.25
CLK_SPI fall time	t_{SPI_clkf}	–	–	100	ns	f_{SPI_clk} < 1 MHz	P_7.2.5.26
CLK_SPI fall time	t_{SPI_clkf}	–	–	$0.1/f_{SPI\_clk}$	ns	f_{SPI_clk} ≥ 1 MHz	P_7.2.5.27
CLK_SPI rise time	t_{SPI_clkr}	–	–	100	ns	f_{SPI_clk} < 1 MHz	P_7.2.5.28
CLK_SPI rise time	t_{SPI_clkr}	–	–	$0.1/f_{SPI\_clk}$	ns	f_{SPI_clk} ≥ 1 MHz	P_7.2.5.29
CLK_SPI lead time	t_{SPI_lead}	100	–	–	ns	–	P_7.2.5.30
CLK_SPI lag time	t_{SPI_lag}	50	–	–	ns	–	P_7.2.5.31
SPI chip select (SCS) rise time	t_{SPI_csr}	–	–	200	ns	t_{SPI_lead} = 100 ns	P_7.2.5.32
SPI chip select (SCS) rise time	t_{SPI_csr}	–	–	$0.2 \times t_{SPI\_lead}$	ns	t_{SPI_lead} > 100 ns	P_7.2.5.33
SPI chip select (SCS) rise time	t_{SPI_csf}	–	–	200	ns	t_{SPI_lead} = 100 ns	P_7.2.5.34
SPI chip select (SCS) fall time	t_{SPI_csf}	–	–	$0.2 \times t_{SPI\_lead}$	ns	t_{SPI_lead} > 100 ns	P_7.2.5.35
SPI data input (SDI) setup	t_{SPI_su}	10	–	–	ns	–	P_7.2.5.36
SPI data input (SDI) hold time	t_{SPI_hi}	10	–	–	ns	–	P_7.2.5.37
SPI data output (SDO) valid after CLK_SPI	t_{SPI_v}	–	–	$36 + (0.1/f_{SPI\_clk})$	ns	$C_{SDO,load}$ = 50 pF; f_{SPI_clk} ≥ 1 MHz	P_7.2.5.38
SPI data output (SDO) valid after CLK_SPI	t_{SPI_v}	–	–	136	ns	$C_{SDO,load}$ = 50 pF; f_{SPI_clk} < 1 MHz	P_7.2.5.39
SPI write propagation delay SDI to SDO	t_{SPI_wpd}	–	–	35	ns	–	P_7.2.5.40
SPI data output (SDO) access	t_{SPI_a}	–	–	50	ns	$C_{SDO,load}$ = 50 pF	P_7.2.5.41
SPI data output (SDO) lag	t_{SPI_lag}	50	–	–	ns	–	P_7.2.5.42

Table 18 Electrical characteristics SPI timing (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
SPI data output (SDO) disable time	t_{SPI_dis}	–	–	100	ns	$C_{SDO,load}$ = 50 pF	P_7.2.5.43
Sequential transfer delay	t_{SPI_td}	350	–	–	ns	–	P_7.2.5.44
Frame duration (SCS "low")	t_{SPI_fl}	–	–	1.85	ms	–	P_7.2.5.45

7.3 Reset generation (ROT signal)

Reset output pin ROT

The reset output pin ROT is an open drain structure. As soon as a reset condition occurs, the device pulls the ROT pin below $V_{ROT,low}$. Once the internal reset signal is released, an internal pull-up current pulls the ROT pin towards the microcontroller supply voltage V_{IOVDD}. An external pull-up resistor can be connected between the ROT and IOVDD pins to speed up the transition. As soon as all events leading to the reset are cleared and the reset delay time expires, the device releases the internal reset signal.

Reset events

Different internal events can trigger a reset signal, see ***Table 26*** for details. Depending on the severity of the error event the device triggers a reset of the following types:

- soft reset: the device forces the ROT pin "low", remains in ACTIVE state and keeps all supply voltages on
- hard reset: the device forces the ROT pin "low", enters FAULT state and turns all supply voltages off

7.3.1 Electrical characteristics ROT

Table 19 Electrical characteristics ROT

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Reset output ROT							
Pull-up current	$I_{ROT,high}$	-180	-120	–	µA	$V_{ROT} \leq 2.0V$	P_7.3.1.1
Output level "low"	$V_{ROT,low}$	–	–	0.4	V	V_{IOVDD} = 5.0 V; I_{ROT} = 3.5 mA	P_7.3.1.2
Output level "low"	$V_{ROT,low}$	–	–	0.4	V	V_{IOVDD} =3.3 V; I_{ROT} = 3.5 mA	P_7.3.1.3
Output fall time	$t_{ROT,fall}$	–	–	25	ns	$C_{ROT,load}$ = 50 pF	P_7.3.1.5
Reset timing							
Reset cycle time	t_{cycle}	–	10	–	µs	–	P_7.3.1.6
Reset delay time adjustment range	t_{RD}	20	–	2000	t_{cycle}	–	P_7.3.1.7
Reset delay time default value		–	100	–	t_{cycle}	***22)***	P_7.3.1.8

22 The default configuration for the reset contributor might not generate a reset at the first start up of the device.

7.4 Interrupt generation (INT signal)

A dedicated interrupt generation block is implemented which is handling requests from independent sources to generate an interrupt. The different requesters are as follows:

- State machine in case:
  - A requested state transition has not been performed successfully
  - A requested state transition has been performed successfully, the microcontroller may only send (additional) SPI commands after an interrupt event has been generated by the system. The purpose of the interrupt event is to inform the microcontroller that a state transition has been performed successfully and that the system can perform SPI communication at full SPI speed.
- Watchdog, an interrupt request is generated if the watchdog is not serviced properly and configured in a way to allow service errors to occur, i.e. an error counter threshold value of more than 2 is configured. In this case an interrupt is generated only if the error counter threshold is not exceeded due to this error
- Error pin monitoring, an interrupt request is generated if the error pin monitoring block detects an error and is configured in a way to allow occurrence of this error for a certain amount of time (recovery delay action enabled). In this case an interrupt is requested if an error is detected by the error pin monitoring and the recovery delay has not expired
- Monitoring Block, an interrupt request is generated based on the defined system reaction.
- Overtemperature warnings and over temperature shutdown of communication LDO.
- Overcurrent conditions of voltage reference or standby LDO.
- SPI block in case an SPI error has occurred.
- Double bit error in the protected configuration.

The device generates an interrupt to inform the connected microcontroller that a non-severe event has occurred. This allows the microcontroller to take proper action based on the source of the interrupt. A single interrupt line exists, which is high on default. All Internal interrupt sources are enabled by default and cannot be disabled.

An interrupt is signaled by pulling the interrupt line low for at least t_{INT} (interrupt min. pulse width) after an internal interrupt condition occurs. The interrupt line will be driven high if all of the ***GSF*** register flag(s) has/ have been cleared via SPI operation earliest after t_{INT} has expired but latest after t_{INTTO} has expired.

Special cases:

- If an interrupt is signaled by pulling INT low and not all interrupt status flags are cleared by the microcontroller within t_{INTTO}, the INT will stay low until t_{INTTO} has expired, but no additional interrupt will be generated. Information about a pending interrupt event can be derived via the INTMISS status flag. This status flag is cleared each time the interrupt line is driven low.
- If an interrupt is signaled by pulling INT low and an additional bit is set in the ***GSF*** register interrupt flag after the interrupt bits have been read by the microcontroller and this outdated information is used to clear the interrupt flags, the interrupt line will stay low until t_{INTTO} has expired, but no additional interrupt will be generated. Information about a pending interrupt event can be derived via a status flag
- After releasing the interrupt line to high, the interrupt line will stay high for at least t_{INTTO} regardless if any additional internal interrupt condition has occurred or not. If a new interrupt event occurs during the delay time out (t_{INTTO}), this will be signaled by generating a new pulse after the delay time out t_{INTTO}

All interrupt sources can only be cleared by a "write-1-to-clear" (w1c) SPI operation, i.e. writing a logic one to the corresponding bit(s) in the interrupt register will clear the event

Interrupt events are organized in a two level approach. The first level (interrupt flag) provides information about different groups of interrupt events. The second level (status flags) provides detailed information about which particular event(s) generated the interrupt. To service an interrupt one would only need to write the interrupt flag register. The status flag registers are only meant to provide detailed information. However all status flags can be cleared as well

An interrupt is only generated after the reset signal to the microcontroller has been released. An interrupt event which occurred while the reset line for the microcontroller is still active is not signaled at the interrupt line but the particular status bit for this event is set.

Details about the timing of the interrupt line are depicted in ***Figure 11***.

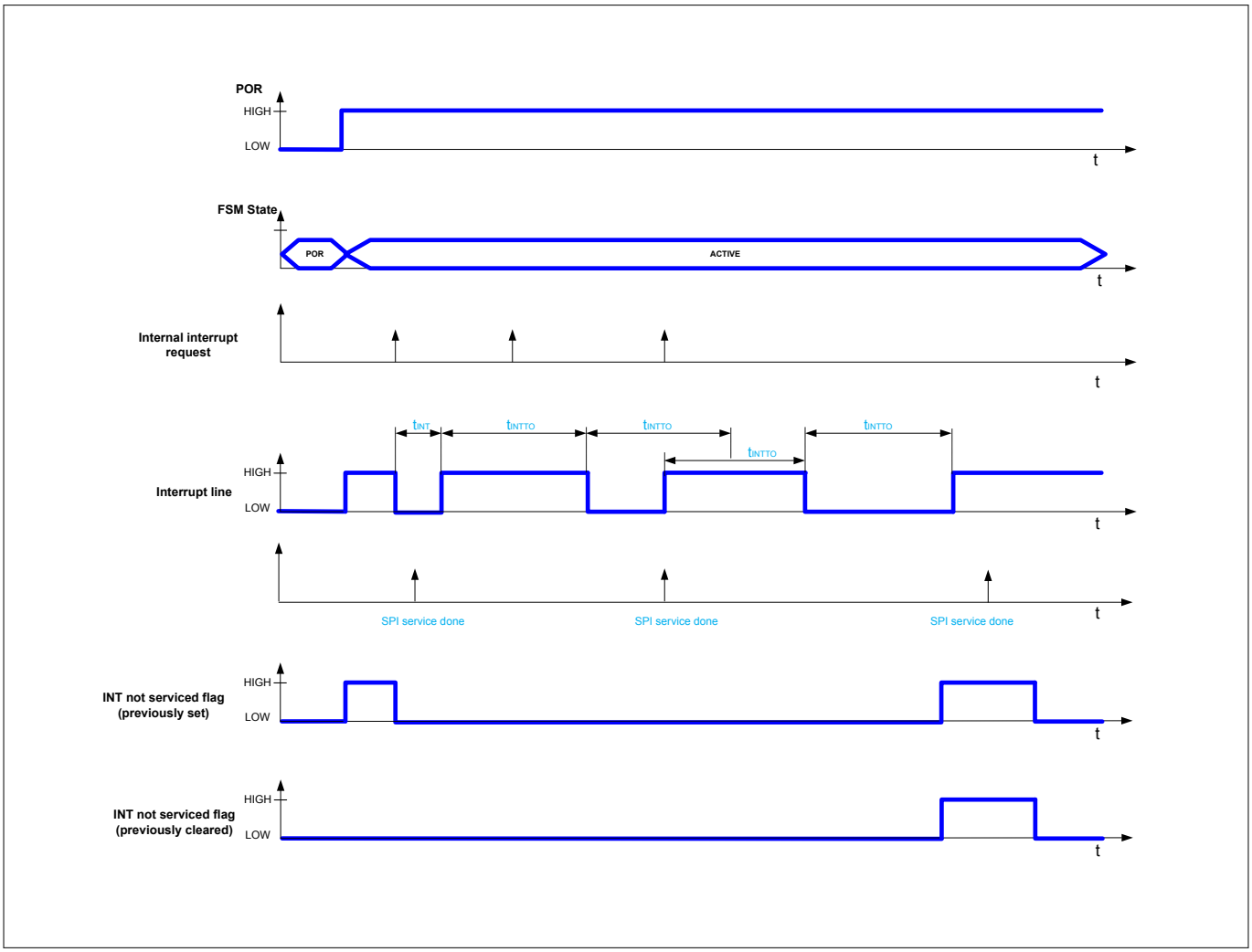


Figure 11 Interrupt timing

Details about the system behavior in case not all interrupt status flags have been cleared are depicted in ***Figure 12***.

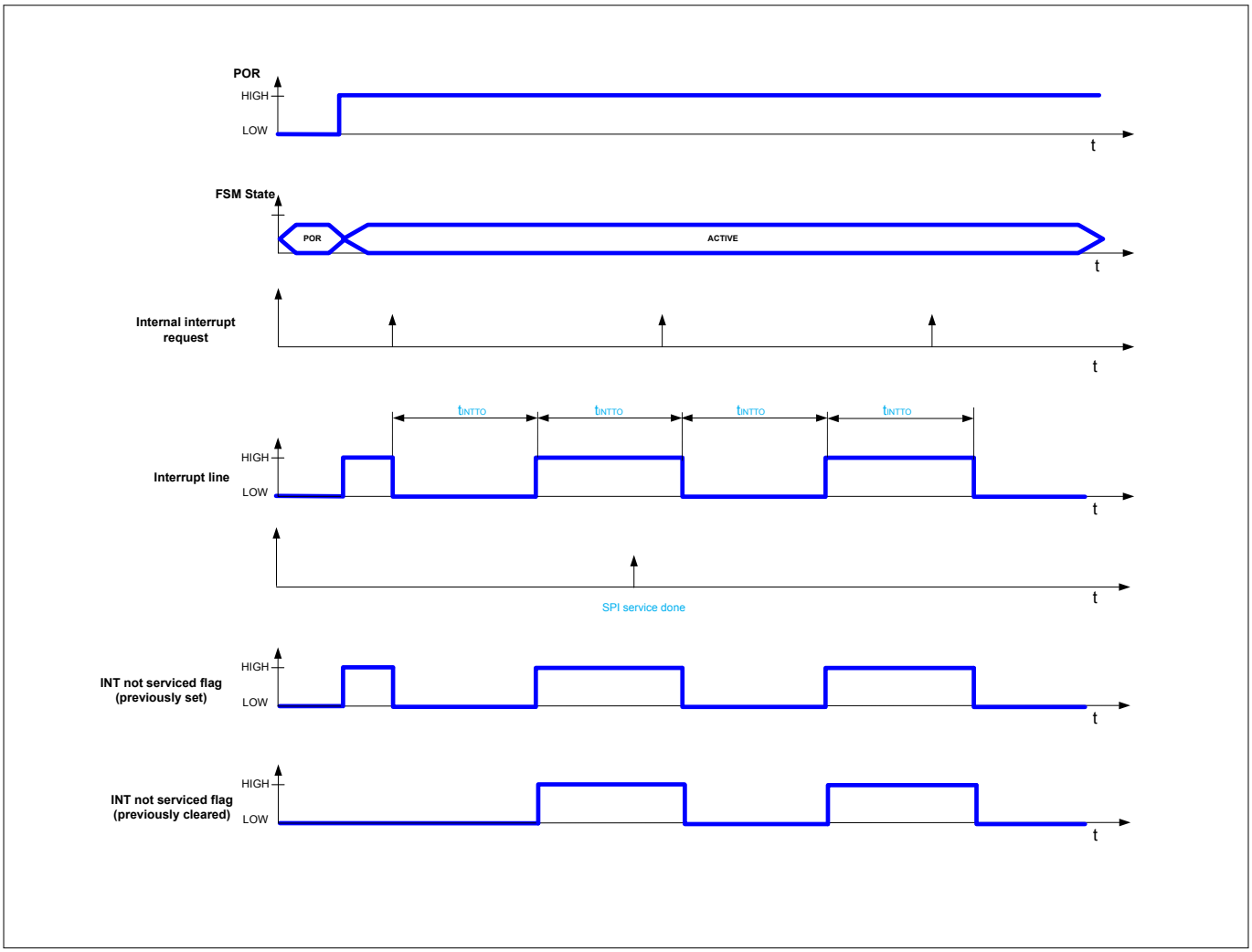


Figure 12 Interrupt timing without service in time

7.4.1 Electrical characteristics INT

Table 20 Electrical characteristics INT

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Interrupt signal INT							
Output level "high"	$V_{INT,high}$	0.7	–	–	V_{IOVDD}	I_{INT} = -7 mA	P_7.4.1.1
Output level "low"	$V_{INT,low}$	–	–	0.7	V	I_{INT} = -5.5 mA	P_7.4.1.2
Output rise time	$t_{INT,rise}$	–	–	25	ns	$C_{INT,load}$ = 50 pF	P_7.4.1.3
Output fall time	$t_{INT,fall}$	–	–	25	ns	$C_{INT,load}$ = 50 pF	P_7.4.1.4
Minimum interrupt "low" time	$t_{INT,low}$	90	100	110	µs	–	P_7.4.1.5

Table 20 Electrical characteristics INT (continued)

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Interrupt "low" timeout	t_{INTTO}	270	300	330	µs	ROT signal for the microcontroller must be released: ROT = "high"	P_7.4.1.6
Minimum interrupt "high" time	$t_{INT,high}$	270	300	330	µs	–	P_7.4.1.7

7.5 Window watchdog

Principle of operation

The integrated window watchdog (WWD) can monitor the microcontroller. The microcontroller monitored must provide periodical triggering during the open windows. Depending on the configuration a trigger event is

- a falling edge on the WDI pin
- an SPI write operation to the register ***WWDSCMD***

After a trigger event the window watchdog indicates either valid WWD triggering or invalid WWD triggering to the WWD error counter and the device terminates the open window.

On valid WWD triggering the device starts a closed window.

If there is no triggering during the open window or if triggering occurs during a closed window, then the window watchdog output indicates invalid WWD triggering to the WWD error counter and a new open window starts.

If the microcontroller does not trigger the window watchdog with a correct timing, then the device indicates that to the microcontroller. If multiple error events occur, then the device sets ROT "low".

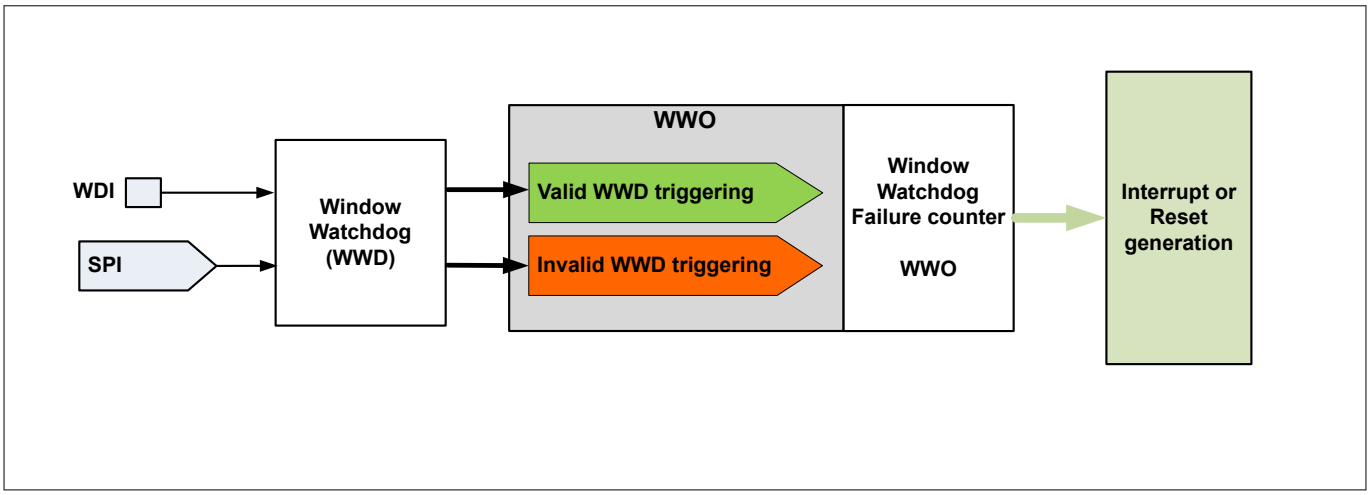


Figure 13 Window watchdog principle of operation

Configuration

The following parameters of the window watchdog can be configured via SPI in ACTIVE:

- The trigger signal can be configured to be pin triggered (pin WDI) or SPI triggered command (register ***WWDSCMD***). The default configuration is the triggering via SPI.
- The duration of the open window and closed window cycles can be modified according to the application needs (combination of cycle time and number of cycles for open window and closed window ***CW***).
- The threshold for the window watchdog error counter overflow can be configured via SPI.

Initialization

As soon as the device sets ROT "high" in INIT state, it activates the window watchdog. After activation the watchdog opens a long open window (LOW) with a duration of t_{LOW}. With the default configuration the window watchdog expects a valid trigger event via SPI during the long open window, while it ignores WDI pin signals. Therefore, glitches at the microcontroller output connected to the WDI have no effect during startup and initialization. During the long open window cycle the microcontroller can change the window watchdog trigger source as well as the timing of the open window and of the closed window. On reconfiguration the window watchdog restarts with the new configuration. The window watchdog starts a regular open window cycle, waiting for a valid trigger signal from the selected trigger source.

If no valid triggering or configuration of the watchdog occurs during the long open window, then the window watchdog recognizes invalid WWD triggering. If the INIT timer expires while invalid WWD triggering persists, then the device generates a soft reset and it sets the ROT pin to "low". After the soft reset the window watchdog

starts a new long open window without indicating an interrupt. The number of repeated long open windows is limited.

If the window watchdog does not recognize valid triggering during the second long open window, then the device generates a hard reset, so it enters FAULT state and it switches off the post regulator output voltages.

Normal operation

On a valid trigger signal during long open window the window watchdog terminates that window and starts a closed window. The closed window has a fixed duration for operation without invalid triggering.

On an in itself valid trigger signal during the closed window the window watchdog recognizes invalid WWD triggering. The window watchdog then terminates the closed window with an invalid trigger signal and starts another open window.

Each Invalid WWD triggering increments the window watchdog error counter by 2 and the device indicates an interrupt. After the closed window the window watchdog starts an open window.

If the window watchdog detects a valid trigger signal during the open window, then it terminates that window and starts the closed window. If the value of the window watchdog error is greater than 0, then valid WWD triggering decrements the window watchdog error counter by 1. If no valid triggering occurs during the open window, then the window watchdog recognizes invalid WWD triggering and increments the window watchdog error counter by 2, it starts a new open window and the device indicates an interrupt.

As long as the window watchdog detects valid triggering during normal operation, it continues to cycle between the open window and the closed window.

Window watchdog output WWO

The window watchdog output WWO is an internal signal. It is connected to the safe window watchdog error counter.

The possible values of WWO are:

- valid WWD triggering
- invalid WWD triggering

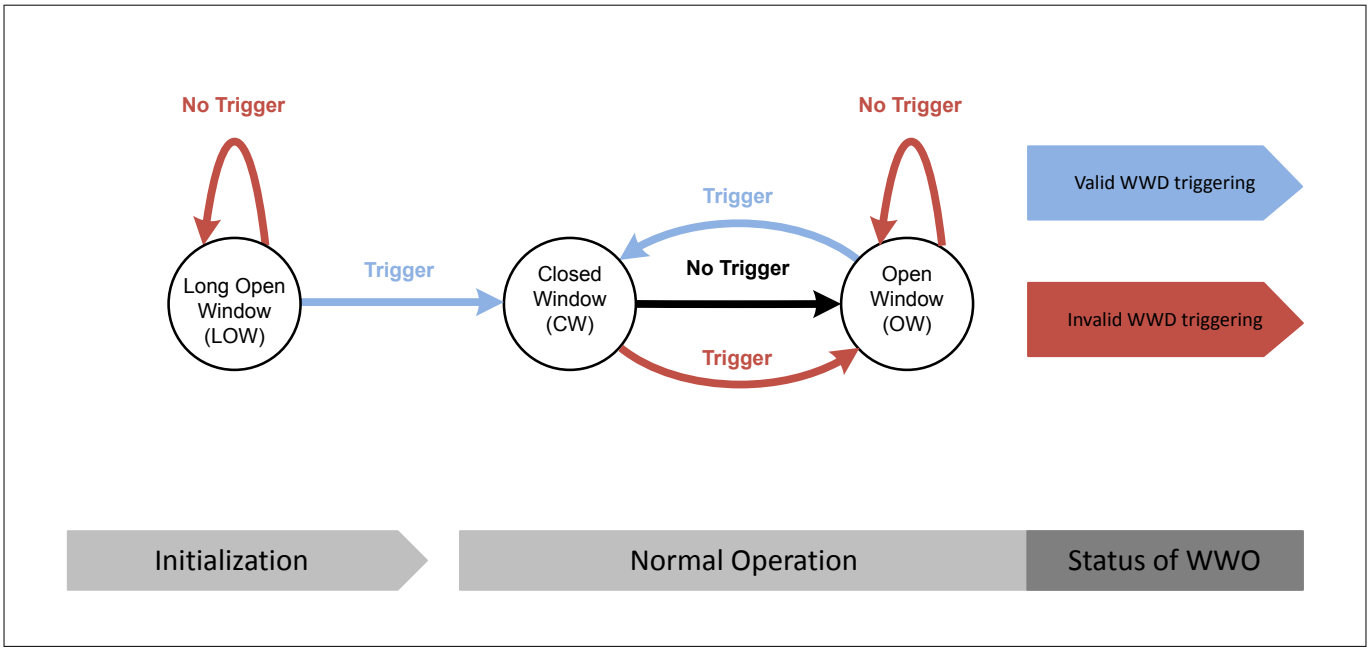


Figure 14 Watchdog state diagram

Description:

- Trigger is either an SPI write operation to register ***WWDSCMD*** or a valid watchdog trigger signal at pin WDI.
- No trigger during the long open window is invalid WWD triggering. The window watchdog opens a new a long open window.

- A trigger during the closed window is invalid WWD triggering.
- No trigger during the closed window results in an open window after the closed window.
- A trigger during the open window is valid WWD triggering. The window watchdog closes the open window and opens the closed window.
- No trigger during the open window is invalid WWD triggering.

Watchdog input WDI

The watchdog input WDI has an integrated pull-down current source I_{WDI}. The watchdog input WDI can have a transition to "high" during the closed window or during the subsequent open window.

Valid trigger signal at WDI

The window watchdog samples the watchdog input WDI periodically with a period of t_{SAM}. A falling edge from $W_{WDI,high}$ to $W_{WDI,low}$ is a valid trigger signal. To improve immunity against both noise and glitches on the WDI pin, the device requires at least two "high" samples followed by two "low" samples for a valid trigger signal. Whether the triggering is valid, the window watchdog decides at the time of the second consecutive "low" sampling point. For example, if the first three samples (two "high", one "low") of the trigger pulse at pin WDI are within the closed window and only the fourth sample (the second "low" sample) is in the open window, then the watchdog output WWO indicates valid WWD triggering.

Invalid triggering at WDI

If the window watchdog does not detect a trigger signal during the open window or if it detects a trigger signal during the closed window, then this is invalid triggering. The watchdog output WDO indicates invalid triggering after no valid trigger during the open window or if it detects a trigger signal during the closed window.

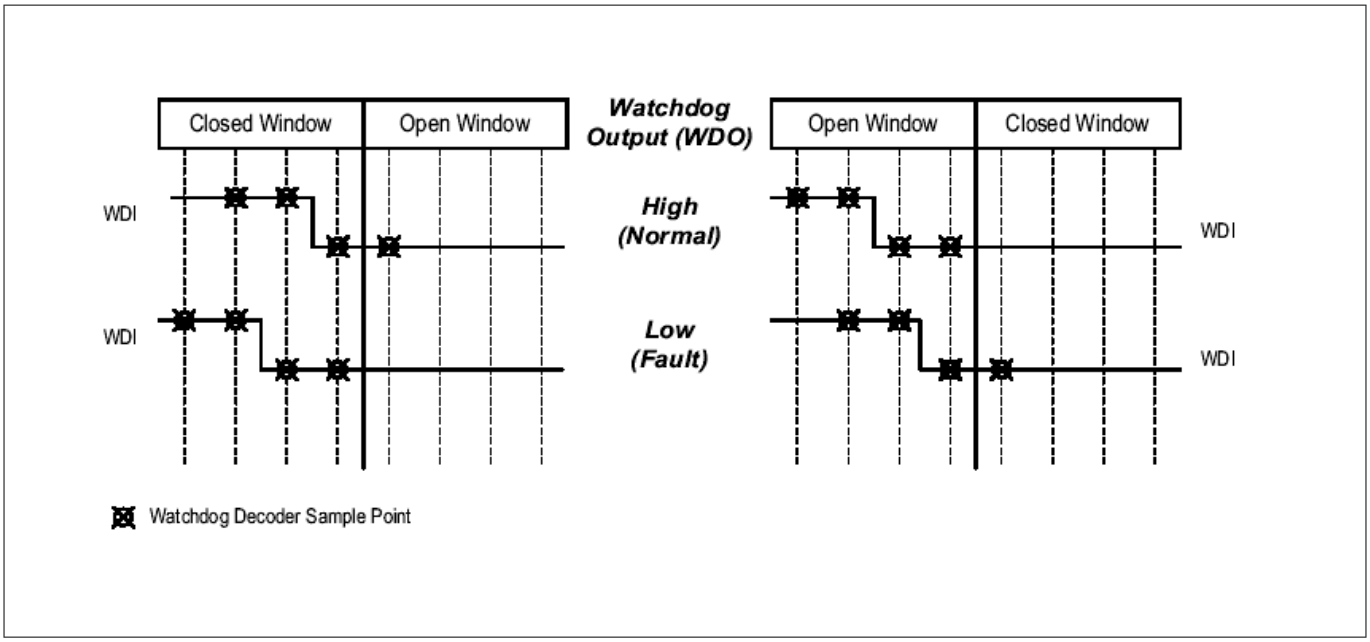


Figure 15 Valid and invalid trigger pulses at WDI pin

7.5.1 Window watchdog timing

Normal operation: correct trigger

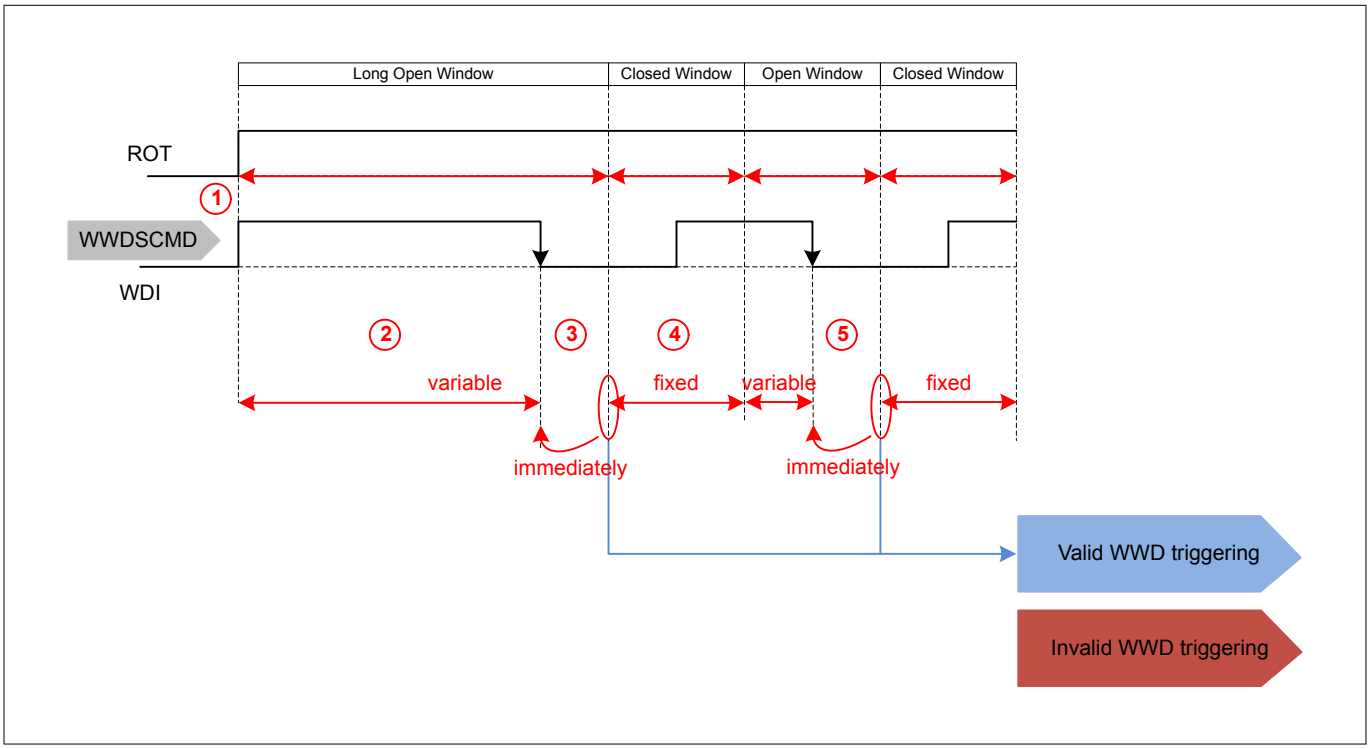


Figure 16 Normal operation: correct trigger

1. If the reset output ROT turns to "high" in ACTIVE state, then the window watchdog starts a long open window. The duration of the first long open window depends on the configured cycle time: 600 ms (WDCYC = 1) or 60 ms (WDCYC = 0).
2. During the long open window the window watchdog waits for valid WWD triggering according to the trigger configuration. The maximum duration of the long open window is fixed. On valid WWD triggering the window watchdog terminates the long open window.
3. The window watchdog starts the closed window.
4. The closed window has a fixed duration of $t_{WD,CW}$, which can be configured via SPI. The closed window starts after the valid trigger signal, that terminates the open window or after the long open window. A transition from "low" to "high" at the WDI pin does not lead to a trigger event.
5. On a valid trigger signal the window watchdog terminates the open window. The duration of the open window depends on when the microcontroller schedules the triggering. This is an example of valid WWD triggering.

Fault: no trigger during open window after initialization

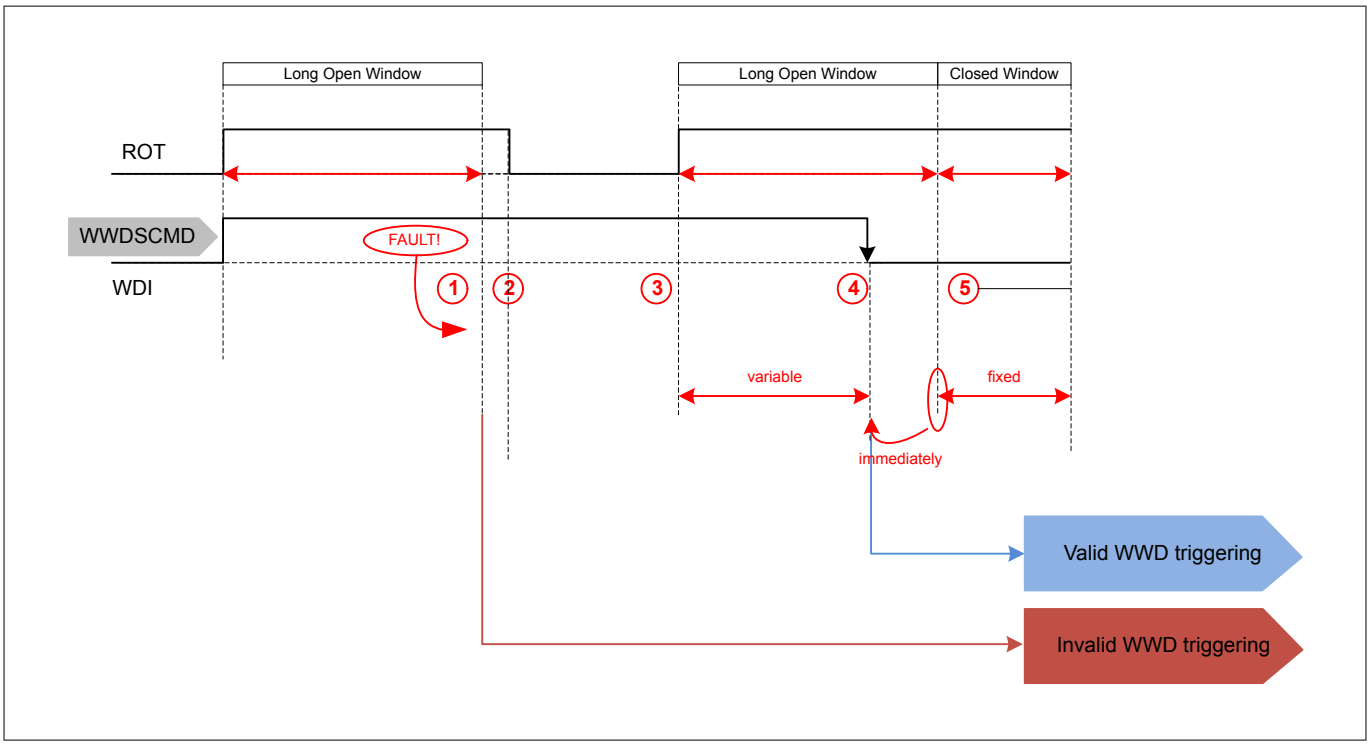


Figure 17 Fault operation: No trigger in open window after initialization

1. The initialization timeout usually finishes slightly before or at the same time as the long open window, which skips the interrupt event. However, the missing valid triggering within the long open window can still lead to an interrupt event after the long open window terminates, which increases the window watchdog error counter by two.
2. The initialization timer expires for the first time. As the window watchdog does not detect valid triggering during ACTIVE state, it generates a soft reset: The device sets ROT to "low", while the output voltages of the post regulators remain on.
3. After the soft reset the pin ROT turns "high" after the power-on reset delay time t_{rd}. The window watchdog opens a long open window, so the microcontroller gets the opportunity to trigger and synchronize to the watchdog period.
4. On valid triggering the window watchdog terminates the open window. The duration of the open window depends on when the triggering occurs. Due to the valid WWD triggering the window watchdog starts a closed window and it decrements the window watchdog error counter by 1.
5. The subsequent closed window lasts for the time $t_{WD,CW}$. Triggering within this closed window is invalid WWD triggering.

Fault: no trigger during open window in steady state

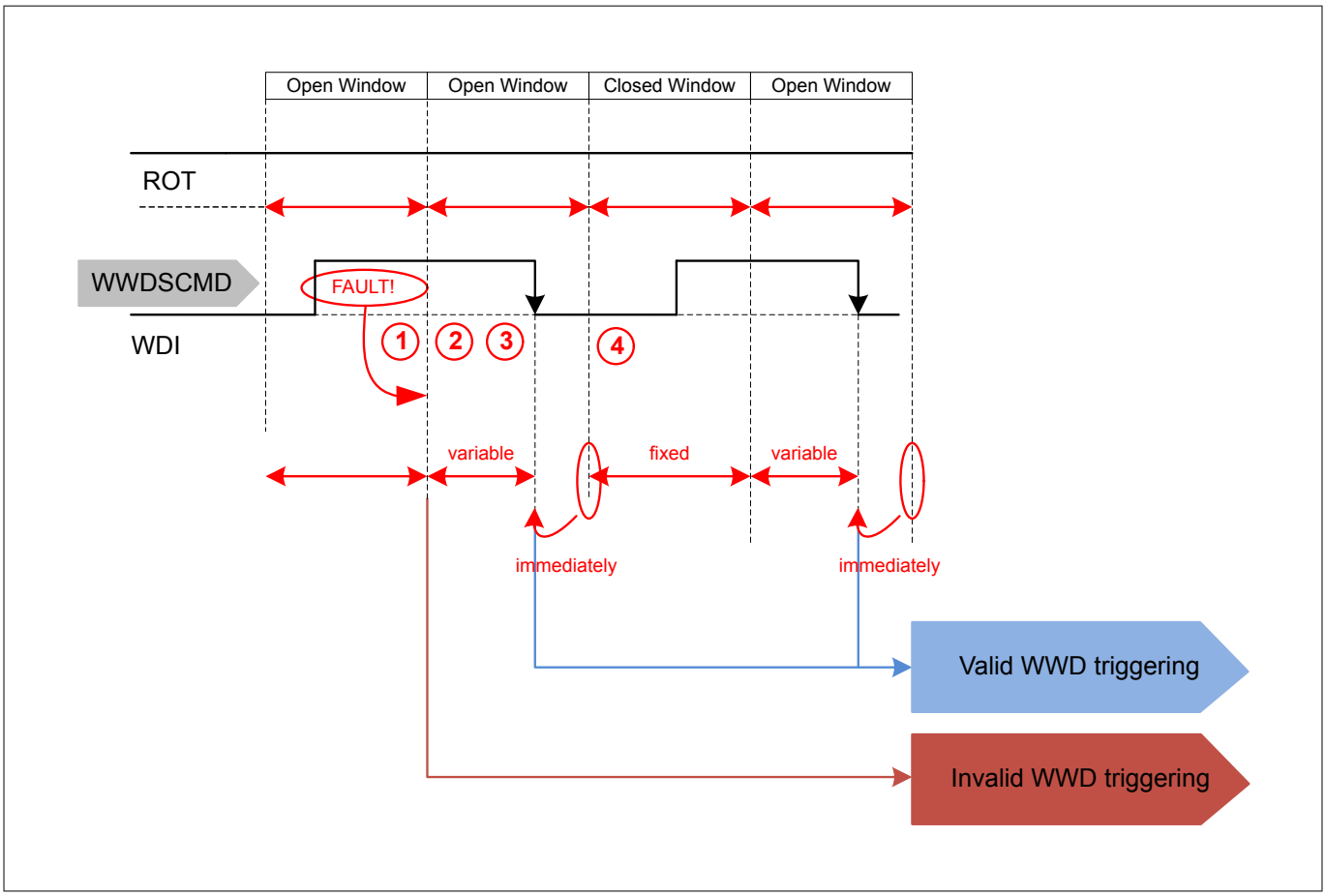


Figure 18 Fault operation: no trigger in open window in steady state

1. If the window watchdog does not detect valid triggering during the entire open window, then it recognizes invalid WWD triggering. The window watchdog indicates this event by an interrupt and it increases the window watchdog error counter by 2.
2. After the invalid WWD triggering the window watchdog starts a new open window with the duration $t_{WD,OW}$ so the microcontroller gets the opportunity to trigger and tosynchronize to the watchdog period.
3. On valid triggering the window watchdog terminates the open window. The duration of the open window depends on when the triggering occurs. Due to the valid WWD triggering the window watchdog starts a closed window and it decrements the window watchdog error counter by 1. If multiple invalid WWD triggering occurs during the open windows, then the window watchdog increases the window watchdog error counter by 2 each time, until it reaches the configured threshold and then generates a reset.
4. The subsequent closed window lasts for the time $t_{WD,CW}$. Triggering during the closed window is invalid WWD triggering.

The behavior of pin ROT depends on the configured value of the window watchdog error counter threshold ΣWWO (***RWDCFG0.WWDETHR***). In this example the amount of invalid triggering does not exceed that threshold.

Fault: wrong trigger during closed window after initialization

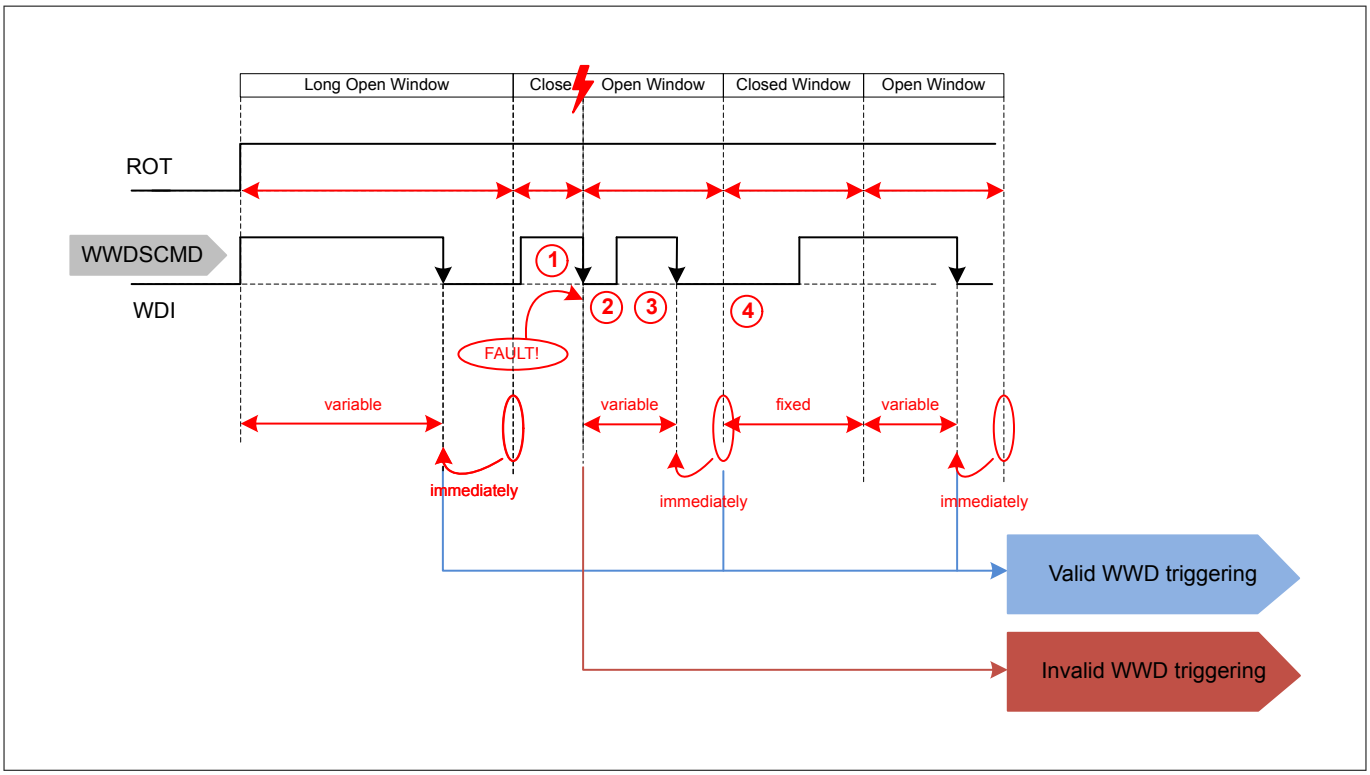


Figure 19 Fault operation: wrong trigger in closed window after initialization

1. Triggering during the closed window is invalid WWD triggering. The window watchdog indicates this event by an interrupt and it increases the window watchdog error counter by 2.
2. Due to the invalid WWD triggering the window watchdog terminates the closed window before the time $t_{WD,CW}$ expires. The window watchdog starts an open window, so the microprocessor gets the opportunity to synchronize to the window watchdog period.
3. During this open window the window watchdog waits for valid triggering. On valid triggering the window watchdog terminates the open window. The duration of the open window depends on when the triggering occurs. Due to the valid triggering the window watchdog starts a closed window and it decrements the window watchdog error counter by 1.
4. The subsequent closed window lasts for the time $t_{WD,CW}$. Triggering during the closed window is invalid WWD triggering.

The behavior of pin ROT depends on the configured value of the window watchdog error counter threshold ΣWWO (***RWDCFG0.WWDETHR***). In this example the amount of invalid triggering does not exceed that threshold.

Fault: wrong trigger during closed window in steady state

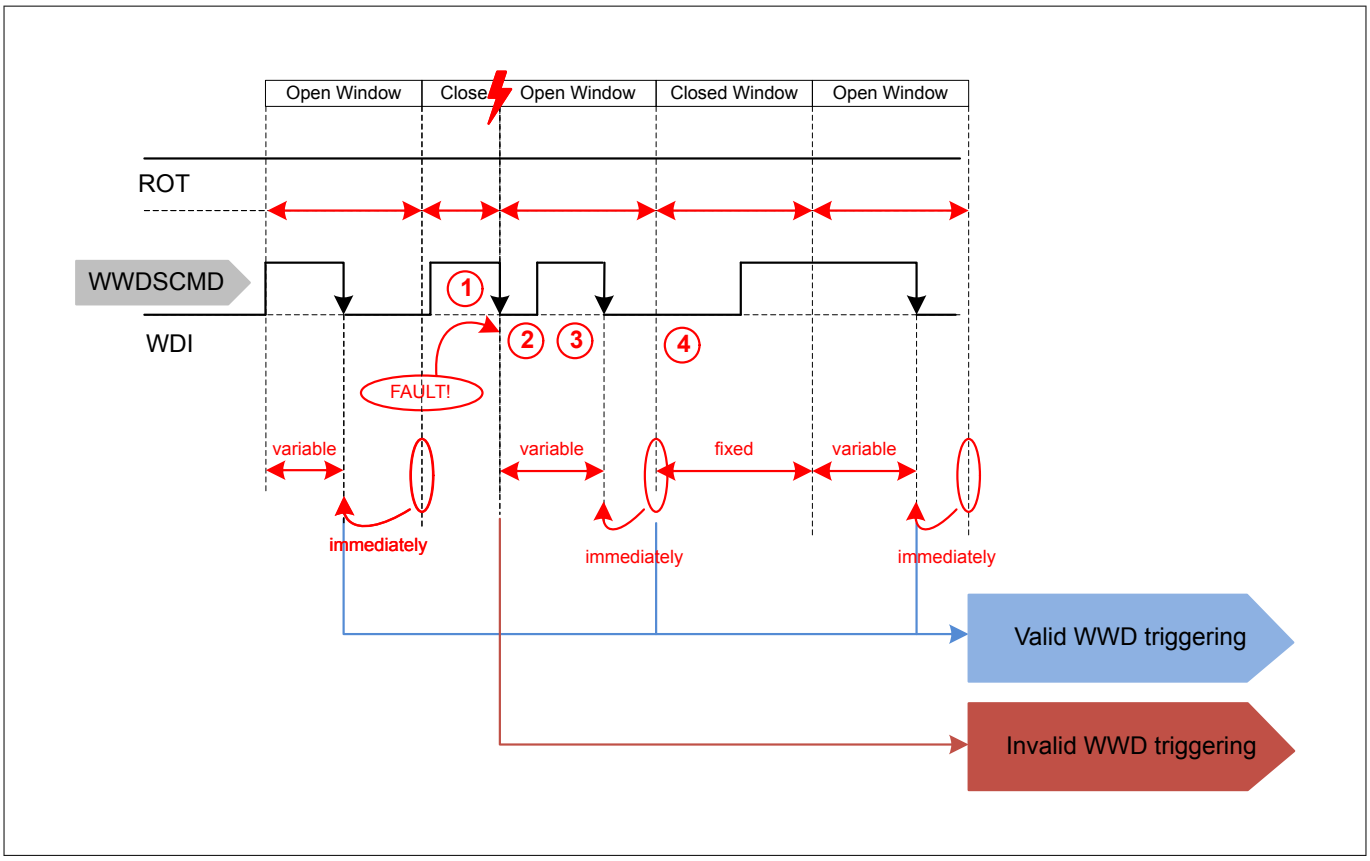


Figure 20 Fault operation: wrong trigger in closed window in steady state

1. Triggering during the closed window is invalid WWD triggering. The window watchdog indicates this event by an interrupt and it increases the window watchdog error counter by 2.
2. Due to the invalid WWD triggering the window watchdog terminates the closed window before the time $t_{WD,CW}$ expires. The window watchdog starts an open window, so the microprocessor gets the opportunity to synchronize to the window watchdog period.
3. During this open window the window watchdog waits for valid triggering. On valid triggering the window watchdog terminates the open window. The duration of the open window depends on when the triggering occurs. Due to the valid triggering the window watchdog starts a closed window and it decrements the window watchdog error counter by 1.
4. The subsequent closed window lasts for the time $t_{WD,CW}$. Triggering during the closed window is invalid WWD triggering.

The behavior of pin ROT depends on the configured value of the window watchdog error counter threshold ΣWWO (***RWDCFG0.WWDETHR***). In this example the amount of invalid triggering does not exceed that threshold.

7.5.2 Electrical characteristics window watchdog

Table 21 Electrical characteristics window watchdog

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Watchdog cycle time, configuration option 0	t_{WDCYC}	9.5	10	10.5	µs	–	P_7.5.1.1
Watchdog cycle time, configuration option 1	t_{WDCYC}	95	100	105	µs	–	P_7.5.1.2
Long open window time	t_{LOW}	570	600	630	ms	–	P_7.5.1.3
Watchdog input WDI							
Watchdog sampling time	t_{WDI_filter}	380	400	420	µs	–	P_7.5.1.4
Valid input level "high"	$V_{WDI, high}$	0.7	–	–	V_{IOVDD}	V_{WDI} increasing	P_7.5.1.5
Valid input level "low"	$V_{WDI, low}$	–	–	0.8	V	V_{WDI} decreasing	P_7.5.1.6
Input hysteresis	$V_{WDI, hyst}$	–	0.06	–	V_{IOVDD}	–	P_7.5.1.7
Pull-down current	I_{WDI}	–	135	330	µA	–	P_7.5.1.8
Input capacitance	C_{WDI}	–	4	15	pF	23)	P_7.5.1.9

7.6 Microcontroller programming mode

The device includes a feature to support programming of microcontroller firmware during production or in the field by preventing periodic reset triggering during the initialization period.

The programming mode can be enabled by pulling the MPS pin "high". In programming mode the reset generation to the microcontroller is modified, so that fault events of microcontroller monitoring features do not generate a microcontroller reset. All other monitoring features that generate a microcontroller reset are still active, see ***Table 25***. The interrupt generation and the state transitions are still active. However, the initialization timer is disabled, so that the device can remain in ACTIVE state.

Operation of the internal state machine and the programming mode are independent, which allows the transition to any state while the microcontroller programming mode is active. However, the microcontroller monitoring is still active and will move the device into ACTIVE state. Therefore, leave the device in ACTIVE state during a programming operation.

Voltage monitoring is active and generates the respective fault events. This may generate interrupts or move the device into FAULT state depending on the nature of the event.

23 Not subject to production test, specified by design.

7.6.1 Electrical characteristics microcontroller programming mode

Table 22 Electrical characteristics microcontroller programming mode

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
MPS pin							
Valid input level "high"	$V_{MPS, high}$	2.4	–	–	V	V_{MPS} increasing	P_7.8.0.1
Valid input level "low"	$V_{MPS, low}$	–	–	0.8	V	V_{MPS} decreasing	P_7.8.0.2
Input hysteresis	$V_{MPS, hys}$	–	350	–	mV	24)	P_7.8.0.3
Pull-down current	I_{MPS}	–	140	330	µA	V_{MPS} = 5.0 V	P_7.8.0.4
Input capacitance	C_{MPS}	–	4	15	pF	24)	P_7.8.0.5

24 Not subject to production test, specified by design.

8 State machine

8.1 State machine introduction

The integrated state machine controls operation in different situations. ***Figure 21*** shows the complete state-diagram. ***Table 23*** and ***Table 24*** describe each state and the transitions.

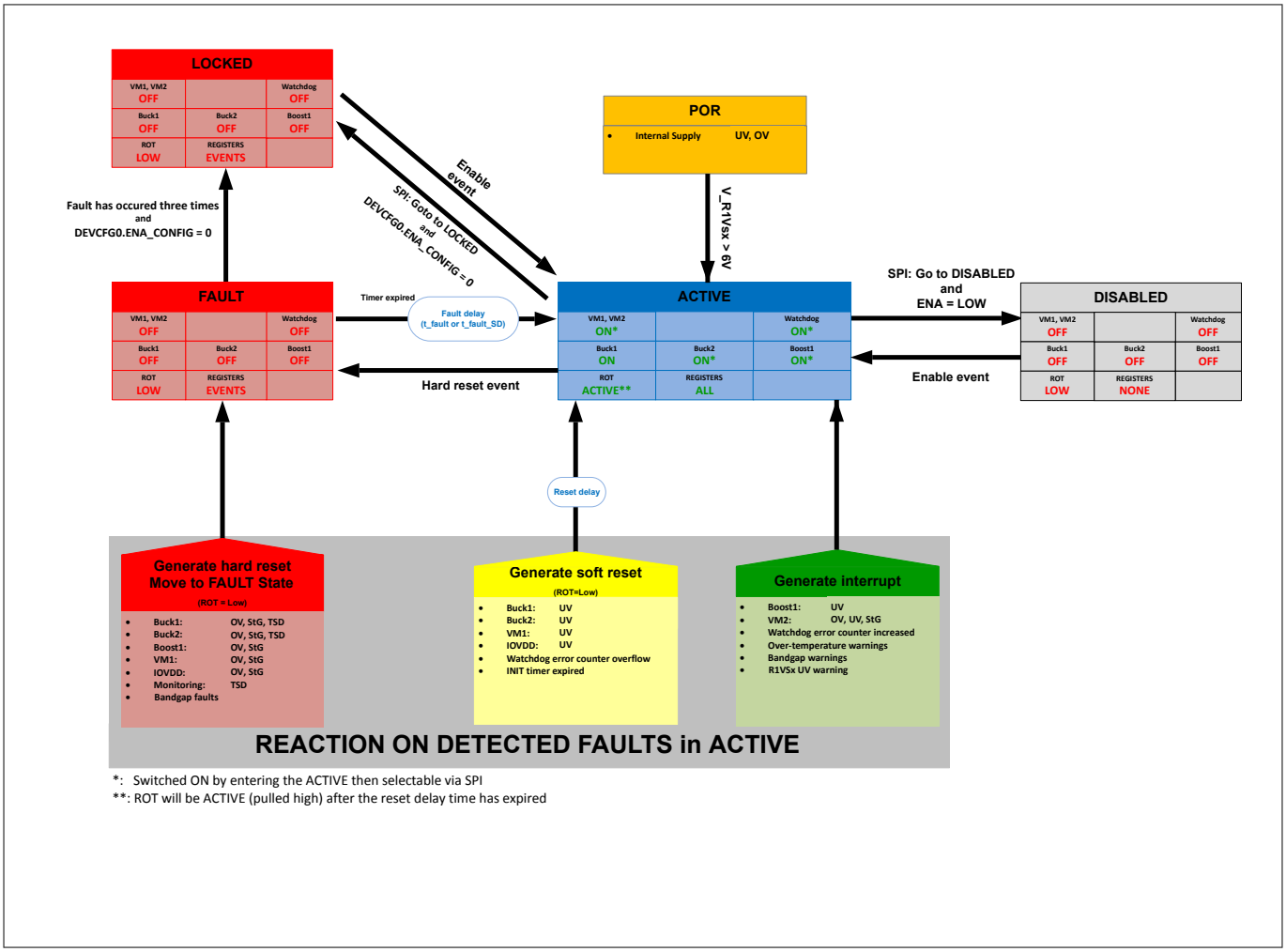


Figure 21 State machine

8.2 Operation states

ACTIVE

The ACTIVE state is the first state that the device enters after power-on. The device powers up all voltage rails and expects to receive configuration from the microcontroller within the initialization time window according to the INIT timer.

On deactivation of the microcontroller reset the INIT timer starts. If the following conditions are fulfilled, then the INIT timer stops:

- The device receives valid SPI communication from the microcontroller.
- The window watchdog is serviced once according to its configuration.

If the INIT timer is not stopped and expires, then the device detects an initialization error. The first initialization error triggers a soft reset, which activates the reset signal ROT, but no state transition. The second initialization error triggers a hard reset, which activates the reset signal ROT and shuts down the supply rails, thus the device enters FAULT state and the system restarts.

The microcontroller can request a transition from ACTIVE state to either DISABLED state or LOCKED state via an SPI command. On an SPI request to change the state to DISABLED or LOCKED the device enters the FAULT state for 20 ms before it enters the requested state. This is done to ensure a proper discharge of the output voltages of all switching regulators before the device is be enabled again.

DISABLED

During DISABLED state the device is powered off and it only monitors the enable signal (ENA) for a valid enable condition. Once a valid enable event is detected, the device enters ACTIVE state and expects configuration from the microcontroller. In DISABLED state the device resets the content of all registers. The device needs to be configured again during the ACTIVE state.

FAULT

On detection of a severe fault the device enters FAULT state. In FAULT state all regulators are switched off and the microcontroller reset (ROT) is asserted. The device remains in FAULT state for the specified fault time prior to a transition into ACTIVE state. In FAULT state the device retains event registers to store the reason for entering the FAULT state. The device resets all other registers.

A soft reset condition on the first detection of a fault condition triggers the reset signal ROT, but no state transition. If the device detects the same soft reset fault condition again, then it increases the severity of the fault to a severe fault. In this case the device enters the FAULT state. This applies for all soft reset faults except the window watchdog error counter overflow.

LOCKED

The device enters LOCKED state after three severe faults, brought on by expiration of the initialization counter or by request of the microcontroller. The power consumption in LOCKED state is reduced. The device remains in LOCKED state until it detects the next valid enable event. In LOCKED state the device only retains a limited set of the event registers to store the reason for entering the LOCKED state. The device resets all other registers.

Table 23 Operational states functional overview.

	ACTIVE		FAULT		LOCKED		DISABLED	
Block or function								
Buck1	on	R	off	R	off	R	off	R
Buck2	on	RW	off	R	off	R	off	R
Boost1	on	RW	off	R	off	R	off	R
VM1	on	RW	off	R	off	R	off	R

Table 23 Operational states functional overview. (continued)

	ACTIVE		FAULT		LOCKED		DISABLED	
Block or function								
VM2	on	RW	off	R	off	R	off	R
–	–	–	–	–	–	–	–	–
Window watchdog	on	RW	off	R	off	R	off	R
–	–	–	–	–	–	–	–	–
Microcontroller reset – ROT	ACTIVE	R	"low"	R	"low"	R	"low"	R
Persistent registers	All registers	-	Event registers	-	Event registers	-	-	-

- on: The function is automatically activated when entering the state . The Function may be configured via SPI within the current state.
- SEL: The function is operating as configured via SPI (during the mode transition or within the current operation mode).
- off: The function is automatically deactivated when entering the operation mode.
- R: The state of the feature cannot be changed in the current operation mode.
- RW: The state of the feature can be changed in the current operation mode.
- "high": The signal is "high" in this operation mode.
- "low": The signal is "low" in this operation mode.
- ACTIVE: The reset signal may generate a reset event (edge) in this operation mode.

8.3 State transitions and trigger signals

This section describes the state transitions of the integrated state machine.

Table 24 shows the static state transitions with the respective source and destination states, the condition required to trigger the state transition and a transition specific action executed during the transition.

Each row refers to one state transition. With multiple conditions in the same row all of the conditions must be met.

Table 24 State transitions

Source	Destination	Condition	Action
Unpowered	ACTIVE	Device supplied First POR event	–
ACTIVE	DISABLED	SPI command and ENA = "low"	–
ACTIVE	LOCKED	SPI command and ENA_CONFIG = 0	–
ACTIVE	FAULT	Hard reset fault detected	–
DISABLED	ACTIVE	Enable event	Generate MCU reset
FAULT	ACTIVE	FAULT timer expires	Generate MCU reset
FAULT	LOCKED	[25] Hard reset fault occurs three times	–
LOCKED	ACTIVE	Enable event	Generate MCU reset

Table 25 and ***Table 26*** show the mapping between the fault events and the associated actions.

Table 25 Event response mapping – voltage rails

Event	Move to FAULT	Move to ACTIVE; Generate RESET	Move to DISABLED	No transition; Generate interrupt
Buck1				
Buck1: OV	X	–	–	–
Buck1: UV	–	X	–	–
Buck1: StG	X	–	–	–
Buck2				
Buck2: OV	X	–	–	–
Buck2: UV	–	X	–	–
Buck2: StG	X	–	–	–
Boost1				
Boost1: OV	X	–	–	–

25 The ENA pin must either be configured as edge-triggered or the ENA pin must be "low" to trigger the transition from FAULT to LOCKED state.

Table 25 Event response mapping – voltage rails (continued)

Event	Move to FAULT	Move to ACTIVE; Generate RESET	Move to DISABLED	No transition; Generate interrupt
Boost1: UV	–	–	–	X
Boost1: StG	X	–	–	–
VM1				
VM1: OV	X	–	–	–
VM1: UV	–	X	–	–
VM1: StG	X	–	–	–
VM2				
VM2: OV	–	–	–	X
VM2: UV	–	–	–	X
VM2: StG	–	–	–	X

Table 26 Event response mapping – other events

Event	Move to FAULT	Move to ACTIVE; Generate RESET	Move to DISABLED	No transition; Generate interrupt
WWD: counter increase	–	–	–	X
WWD: counter overflow	–	X	–	–
INIT timer expired – first time	–	X	–	–
INIT timer expired – second time	X	–	–	–
–	–	–	–	–
Internal protection: band gap warning	–	–	–	X
Internal protection: band gap fault	X	–	–	–
IOVDD: OV	X	–	–	–
IOVDD: UV	–	X	–	–
IOVDD: StG	X	–	–	–
Internal protection: internal supplies (UV,OV)	–	[26] X	–	–
–	–	–	–	–
Buck1: OT warning	–	–	–	X
Buck1: OT fault	X	–	–	–

26 If the TLF30681QVS01 detects an UV or OV fault condition on the internal supplies, then it turns off completely. The TLF30681QVS01 enters the ACTIVE state when the UV or OV condition is no longer present.

Table 26 Event response mapping – other events (continued)

Event	Move to FAULT	Move to ACTIVE; Generate RESET	Move to DISABLED	No transition; Generate interrupt
Buck2: OT warning	–	–	–	X
Buck2: OT fault	X	–	–	–
Monitoring: OT warning	–	–	–	X
Monitoring: OT fault	X	–	–	–

Figure 22 shows the timing of soft reset generation and hard reset generation after an initialization error.

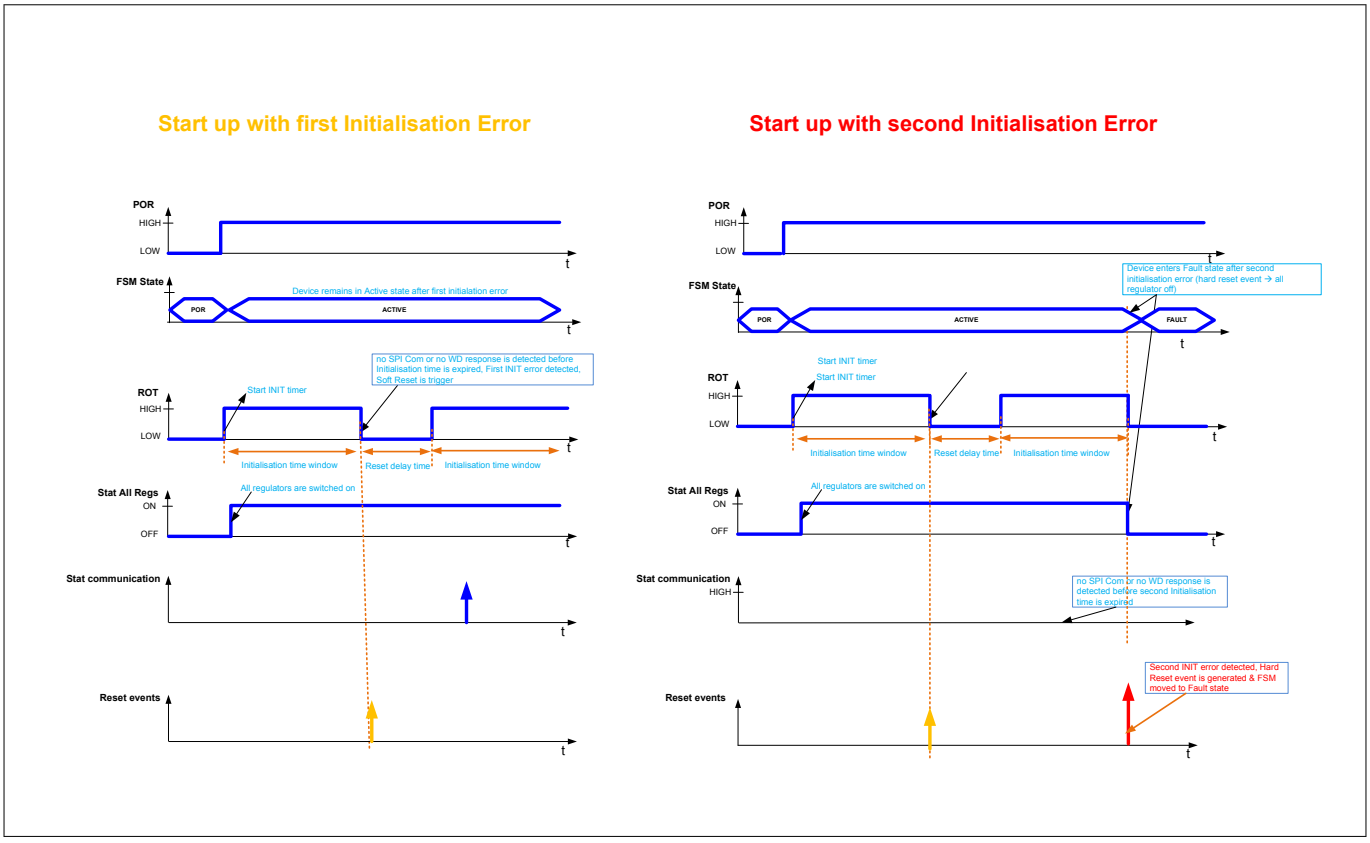


Figure 22 Reset generation timing

Figure 23 shows the reset counter and the transition to LOCKED mode after three initializations failure.

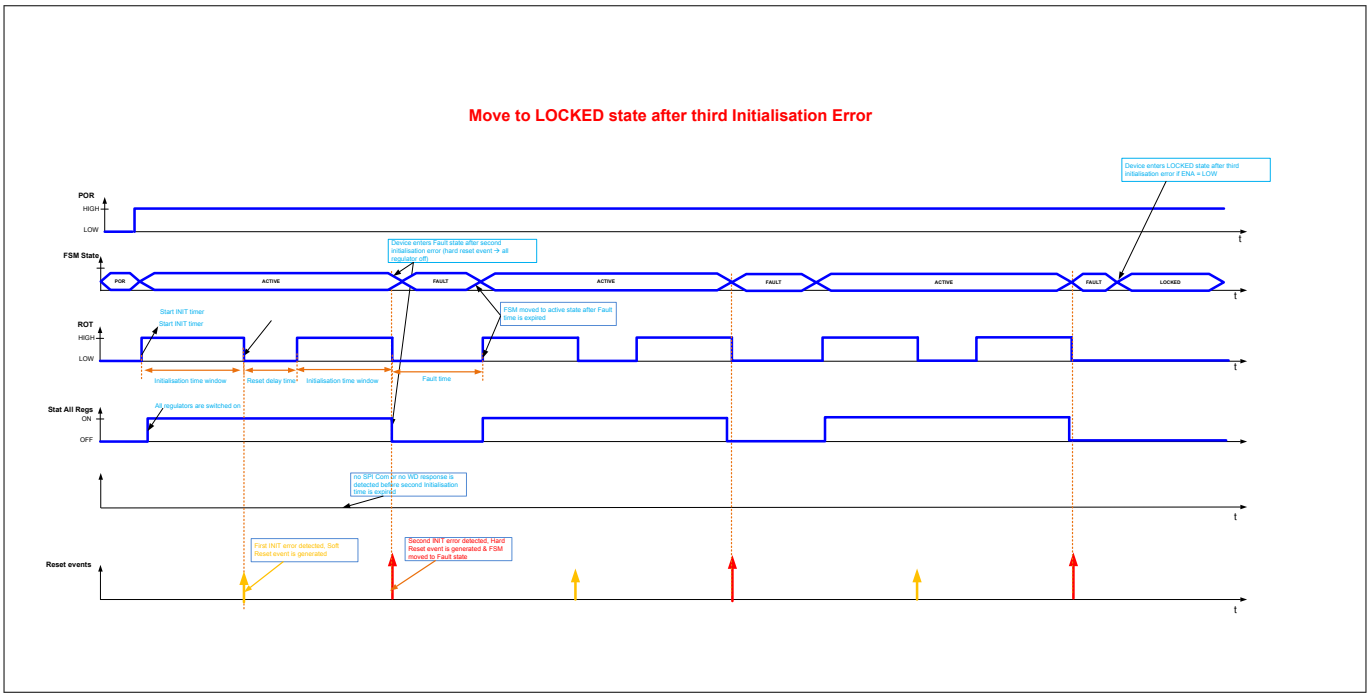


Figure 23 Hard reset counter

8.4 Electrical characteristics state machine

Table 27 Electrical characteristics state machine

T_j = -40°C to 150°C; V_{R1VSx} = 3.7 V to 35 V; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Parameter	Symbol	Values			Unit	Note or condition	Number
		Min.	Typ.	Max.			
Initialization timeout (INIT timer)	t_{INIT}	550	600	650	ms	–	
Fault time	t_{Fault}	–	20	–	ms	–	
Fault time TSD	$t_{Fault,TSD}$	–	1000	–	ms	–	
State transition time	t_{trans}	–	–	100	µs	–	

9 SPI registers

Table 28 Abbreviations

R0	Register is reset on a POR event and on a transition into DISABLED state.
R1	Register is reset with reset class R0 and additionally on a transition into LOCKED state.
R2	Register is reset with reset class R1 and additionally on a microcontroller reset.
r	Bit is readable (read-only).
rw	Bit is readable and writable (read-write).
rw1p	Bit is protected. Read data is inverted. Write via LOCK/UNLOCK mechanism only.
rw1c	Bit is readable and can be cleared by a write operation with 1. Bit is updated based on hardware inputs (flags).
rwhc	Bit is readable and writable. After a write operation with 1 an operation is triggered which upon its completion sets the bit to 0.
rwhu	Bit is readable and writable. Bit is updated based on hardware inputs (flags).

Table 29 Register overview

Register ID	Description	Address	Reset Value	Reset Class	Page
DEVCFG0	*Device configuration 0*	00_H	$F3_H$	R0	Page *88*
CLKCFG0	*Clock configuration 0*	01_H	00_H	R2	Page *89*
CLKCFG1	*Clock configuration 1*	02_H	04_H	R2	Page *90*
PROTCFG	*Configuration protection*	03_H	00_H	R2	Page *102*
PWDCFG0	*Protected watchdog configuration 0*	06_H	$9B_H$	R2	Page *91*
RWDCFG0	*Read-only watchdog configuration 0*	07_H	$9B_H$	R2	Page *94*
PWDCFG1	*Protected watchdog configuration 1*	08_H	46_H	R2	Page *92*
RWDCFG1	*Read-only watchdog configuration 1*	09_H	46_H	R2	Page *95*
PWDCFG2	*Protected Watchdog Configuration 2*	$0A_H$	78_H	R2	Page *93*
RWDCFG2	*Read-only watchdog configuration 2*	$0B_H$	78_H	R2	Page *96*
B2VCTRL	*Buck2 output voltage control*	10_H	02_H	R1	Page *100*
B2VCTRLN	*Buck2 output voltage control inverted*	11_H	$0D_H$	R1	Page *101*
GSF	*Global status flags*	$1A_H$	00_H	R0	Page *104*
SYSSF0-QM	*System status flags – faults*	$1B_H$	00_H	R0	Page *106*
SYSSF1-QM	*System status flags – interrupts*	$1C_H$	00_H	R1	Page *107*
MCUSF0-QM	*Microcontroller status flags 0 – faults*	$1D_H$	00_H	R0	Page *109*
MCUSF1-QM	*Microcontroller status flags 1 – warnings*	$1E_H$	00_H	R1	Page *110*
SPISF	*SPI status flags*	$1F_H$	00_H	R1	Page *111*

Table 29 Register overview (continued)

Register ID	Description	Address	Reset Value	Reset Class	Page
MONSF0	*Voltage monitoring status flags 0 – short to ground*	20_H	00_H	R0	Page *112*
MONSF1	*Voltage monitoring status flags 1 – overvoltage*	21_H	00_H	R0	Page *113*
MONSF2	*Voltage monitoring status flags 2 – undervoltage*	22_H	00_H	R0	Page *114*
OTSF0	*Overtemperature events 0 – faults*	23_H	00_H	R0	Page *115*
OTSF1	*Overtemperature flags 1 – warnings*	24_H	00_H	R1	Page *116*
OCSF1	*Overcurrent flags – warnings*	25_H	00_H	R1	Page *117*
OTSTAT0	*Overtemperature status 0 – warnings*	26_H	00_H	R1	Page *118*
VMONSTAT0	*Voltage monitoring*	27_H	00_H	R1	Page *119*
DEVSTAT	*Device state information*	28_H	00_H	R1	Page *121*
PROTSTAT	*Protection status information*	29_H	01_H	R2	Page *122*
WWDSTAT	*Window watchdog status information*	$2A_H$	00_H	R2	Page *123*
WWDSCMD	*Window watchdog service command*	33_H	00_H	R2	Page *103*
DEVCTRL	*Device state control*	34_H	00_H	R1	Page *98*
DEVCTRLN	*Device state control inverted*	35_H	00_H	R1	Page *99*
MPSSTAT0	*Microcontroller programming support status information*	37_H	03_H	R1	Page *124*
B2VSTAT	*Buck2 output voltage status*	39_H	02_H	R1	Page *125*
HWDECT0	*Hardware option information*	$3B_H$	$D3_H$	R1	Page *127*
DEVID	*Device identification*	$3C_H$	30_H	R1	Page *128*

9.1 SPI register definition

9.1.1 Device configuration registers (device startup default configuration)

9.1.1.1 Register DEVCFG0

DEVCFG0 RMAP: 1 Address: 00_H

Device configuration 0 PAGE: 0 Reset Value: $F3_H$

7	6	5	4	3	2	1	0
VM2ENAS	**VM1ENAS**	**BOOST1ENAS**	**BUCK2ENAS**	**ENA_CONFIG**	**RESDEL**		
r	r	r	r	rw	rw		

Field	Bits	Type	Description
VM2ENAS	7	r	**External voltage monitoring 2 enable at start up** 0_H , disabled 1_H , enabled Reset: 1_H
VM1ENAS	6	r	**External voltage monitoring 1 enable at start up** 0_H , disabled 1_H , enabled Reset: 1_H
BOOST1ENAS	5	r	**Boost1 enable at start up** 0_H , disabled 1_H , enabled Reset: 1_H
BUCK2ENAS	4	r	**Buck2 enable at start up** 0_H , disabled 1_H , enabled Reset: 1_H
ENA_CONFIG	3	rw	**ENA pin configuration** 0_H , edge triggered 1_H , level sensitive Reset: 0_H
RESDEL	2:0	rw	**Reset release delay time** 00_H , 200 µs 01_H , 400 µs 02_H , 800 µs 03_H , 1 ms 04_H , 2 ms 05_H , 4 ms 06_H , 10 ms 07_H , 20 ms Reset: 03_H

9.1.1.2 Register CLKCFG0

CLKCFG0 RMAP: X Address: 01_H

Clock configuration 0 PAGE: 2 Reset Value: 00_H

7	6	5	4	3	2	1	0
nu	**PHBUCK2**	**PHBUCK1**	**PHSO**	**nu**	**SSEN**	**SIEN**	**SOEN**
r	rw	rw	rw	r	rw	rwhc	rw

Field	Bits	Type	Description
nu	7	r	**Not used**
PHBUCK2	6	rw	**Buck2 phase alignment** 0_H , 0° phase shift 1_H , 180° phase shift Reset: 0_H
PHBUCK1	5	rw	**Buck1 phase alignment** 0_H , 0° phase shift 1_H , 180° phase shift Reset: 0_H
PHSO	4	rw	**External clock synchronization phase alignment** 0_H , 0° phase shift 1_H , 180° phase shift Reset: 0_H
nu	3	r	**Not used**
SSEN	2	rw	**Spread spectrum modulation enable** 0_H , disabled 1_H , enabled Reset: 0_H
SIEN	1	rwhc	**External clock synchronization input enable** 0_H , disabled 1_H , enabled Reset: 0_H
SOEN	0	rw	**External clock synchronization output enable** 0_H , disabled 1_H , enabled Reset: 0_H

9.1.1.3 Register CLKCFG1

CLKCFG1 RMAP: X Address: 02_H

Clock configuration 1 PAGE: 2 Reset Value: 04_H

7	6	5	4	3	2	1	0
nu					**FREQSEL**		
r					rw		

Field	Bits	Type	Description
nu	7:3	r	**Not used**
FREQSEL	2:0	rw	**Main switching frequency** 0_H , 1.8 MHz 1_H , 1.9 MHz 2_H , 2.0 MHz 3_H , 2.1 MHz 4_H , 2.2 MHz 5_H , 2.3 MHz 6_H , 2.4 MHz 7_H , 2.5 MHz Reset: 4_H

9.1.1.4 Register PWDCFG0

PWDCFG0 RMAP: X Address: 06_H

Protected watchdog configuration 0 PAGE: 2 Reset Value: $9B_H$

7	6	5	4	3	2	1	0
WWDETHR				**WWDEN**	**nu**	**WWDTSEL**	**WDCYC**
rwp				rwp	r	rwp	rwp

Field	Bits	Type	Description
WWDETHR	7:4	rwp	**Window watchdog error threshold** 0_H 0 1_H 1 ... F_H 15 Reset: 9_H
WWDEN	3	rwp	**Window watchdog enable** 0_B , disabled 1_B , enabled 1_B
nu	2	r	**Not used**
WWDTSEL	1	rwp	**Window watchdog trigger selection** 0_B , external WDI input used as WWD trigger 1_B , WWD is triggered by SPI write to WWDSCMD register 1_B
WDCYC	0	rwp	**Watchdog cycle time** 0_B , 10 µs tick period 1_B , 100 µs tick period 1_B

9.1.1.5 Register PWDCFG1

PWDCFG1 RMAP: X Address: 08_H

Protected watchdog configuration 1 PAGE: 2 Reset Value: 46_H

7	6	5	4	3	2	1	0
nu	**CW**						
r	rwp						

Field	Bits	Type	Description
nu	7	r	**Not used**
CW	6:0	rwp	**Window watchdog closed window size** 00_H 0 watchdog cycles 01_H 50 watchdog cycles 02_H 100 watchdog cycles ... $7F_H$ 6350 watchdog cycles Reset: 46_H

9.1.1.6 Register PWDCFG2

PWDCFG2 RMAP: X Address: $0A_H$

Protected Watchdog Configuration 2 PAGE: 2 Reset Value: 78_H

7	6	5	4	3	2	1	0
nu	**OW**						
r	rwp						

Field	Bits	Type	Description
nu	7	r	**Not used**
OW	6:0	rwp	**Window watchdog open window size** 00_H 50 watchdog cycles 01_H 50 watchdog cycles 02_H 100 watchdog cycles ... $7F_H$ 6350 watchdog cycles Reset: 78_H

9.1.2 Read-only registers for protected configuration registers

9.1.2.1 Register RWDCFG0

RWDCFG0 RMAP: X Address: 07_H

Read-only watchdog configuration 0 PAGE: 2 Reset Value: $9B_H$

7	6	5	4	3	2	1	0
WWDETHR				**WWDEN**	**nu**	**WWDTSEL**	**WDCYC**
r				r	r	r	r

Field	Bits	Type	Description
WWDETHR	7:4	r	**Window watchdog error threshold ACTIVE** 0_H 0 1_H 1 ... F_H 15 Reset: 9_H
WWDEN	3	r	**Window watchdog enable STATUS** 0_B , disabled 1_B , enabled 1_B
nu	2	r	**Not used**
WWDTSEL	1	r	**Window watchdog trigger selection ACTIVE** 0_B , external WDI input used as WWD trigger 1_B , WWD is triggered by SPI write to WWDSCMD register 1_B
WDCYC	0	r	**Watchdog cycle time ACTIVE** 0_B , 10 µs tick period 1_B , 100 µs tick period 1_B

9.1.2.2 Register RWDCFG1

RWDCFG1 RMAP: X Address: 09_H

Read-only watchdog configuration 1 PAGE: 2 Reset Value: 46_H

7	6	5	4	3	2	1	0
nu				**CW**			
r				r			

Field	Bits	Type	Description
nu	7	r	**Not used**
CW	6:0	r	**Window watchdog closed window size ACTIVE** 00_H 0 watchdog cycles 01_H 50 watchdog cycles 02_H 100 watchdog cycles ... $7F_H$ 6350 watchdog cycles Reset: 46_H

9.1.2.3 Register RWDCFG2

RWDCFG2 RMAP: X Address: $0B_H$

Read-only watchdog configuration 2 PAGE: 2 Reset Value: 78_H

7	6	5	4	3	2	1	0
nu	**OW**						
r	r						

Field	Bits	Type	Description
nu	7	r	**Not used**
OW	6:0	r	**Window watchdog open window size ACTIVE** 00_H 50 watchdog cycles 01_H 50 watchdog cycles 02_H 100 watchdog cycles ... $7F_H$ 6350 watchdog cycles Reset: 78_H

9.1.3 Protected device configuration registers

The registers in this section are protected by a defined access procedure. This procedure is based on the access to two individual registers writing inverted information. For detailed information please refer to ***SPI write initiated state transition request and regulator configuration***.

9.1.3.1 Register DEVCTRL

DEVCTRL RMAP: X Address: 34_H

Device state control PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
VM2EN	**VM1EN**	**BOOST1EN**	**BUCK2EN**	**nu**	**STATEREQ**		
rw	rw	rw	rw	r	rw		

Field	Bits	Type	Description
VM2EN	7	rw	**External voltage monitoring 2 enable request** 0_H , disable 1_H , enable Reset: 0_H
VM1EN	6	rw	**External voltage monitoring 1 enable request** 0_H , disable 1_H , enable Reset: 0_H
BOOST1EN	5	rw	**Boost1 enable request** 0_H , disable 1_H , enable Reset: 0_H
BUCK2EN	4	rw	**Buck2 enable request** 0_H , disable 1_H , enable Reset: 0_H
nu	3	r	**Not used**
STATEREQ	2:0	rw	**Device state request** 00_H Reserved 01_H , ACTIVE state 02_H Reserved 03_H , DISABLED state 04_H Reserved 05_H Reserved 06_H Reserved 07_H , LOCKED state Reset: 00_H

9.1.3.2 Register DEVCTRLN

DEVCTRLN RMAP: X Address: 35_H

Device state control inverted PAGE: 1 Reset Value: 00_H

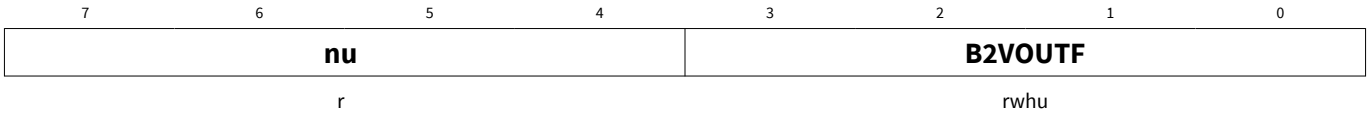
7	6	5	4	3	2	1	0
VM2EN	**VM1EN**	**BOOST1EN**	**BUCK2EN**	**nu**	**STATEREQ**		
rw	rw	rw	rw	r	rw		

Field	Bits	Type	Description
VM2EN	7	rw	**External voltage monitoring 2 enable request** 0_H , enable 1_H , disable Reset: 0_H
VM1EN	6	rw	**External voltage monitoring 1 enable request** 0_H , enable 1_H , disable Reset: 0_H
BOOST1EN	5	rw	**Boost1 enable request** 0_H , enable 1_H , disable Reset: 0_H
BUCK2EN	4	rw	**Buck2 enable request** 0_H , enable 1_H , disable Reset: 0_H
nu	3	r	**Not used**
STATEREQ	2:0	rw	**Device state request** 07_H Reserved 06_H , ACTIVE state 05_H Reserved 04_H , DISABLED state 03_H Reserved 02_H Reserved 01_H Reserved 00_H , LOCKED state Reset: 00_H

9.1.3.3 Register B2VCTRL

B2VCTRL RMAP: X Address: 10_H

Buck2 output voltage control PAGE: 1 Reset Value: 02_H



Field	Bits	Type	Description
nu	7:4	r	**Not used**
B2VOUTF	3:0	rwhu	**Buck2 output voltage setting fine resolution** 0_H , 1.30 V 1_H , 1.20 V 2_H , 1.25 V 3_H , 1.15 V 4_H , 1.10 V 5_H , 1.00 V 6_H , 1.05 V 7_H , 0.95 V 8_H , 0.90 V Reset: 2_H

9.1.3.4 Register B2VCTRLN

B2VCTRLN RMAP: X Address: 11_H

Buck2 output voltage control inverted PAGE: 1 Reset Value: $0D_H$

7	6	5	4	3	2	1	0
nu				**B2VOUTF**			
r				rwhu			

Field	Bits	Type	Description
nu	7:4	r	**Not used**
B2VOUTF	3:0	rwhu	**Buck2 output voltage setting fine resolution** F_H 1.30 V E_H 1.20 V D_H 1.25 V C_H 1.15 V B_H 1.10 V A_H 1.00 V 9_H 1.05 V 8_H 0.95 V 7_H 0.90 V Reset: D_H

9.1.4 General registers

9.1.4.1 Register PROTCFG

PROTCFG RMAP: X Address: 03_H

Configuration protection PAGE: 2 Reset Value: 00_H

7	6	5	4	3	2	1	0
KEY							
rw							

Field	Bits	Type	Description
KEY	7:0	rw	**Protection key** Reset: 00_H

9.1.4.2 Register WWDSCMD

WWDSCMD RMAP: X Address: 33_H

Window watchdog service command PAGE: 2 Reset Value: 00_H

7	6	5	4	3	2	1	0
TRIG_STATUS	**nu**						**TRIG**
r	r						rw

Field	Bits	Type	Description
TRIG_STATUS	7	r	**Window watchdog last trigger received via SPI** Reset: 00_H
nu	6:1	r	**Not used**
TRIG	0	rw	**Window watchdog trigger command** Reset: 00_H

9.1.5 Event status registers

The event status registers of the device are organized hierarchically. The global status register is used to collect information of the status flags set in other registers to enable the user to speed up the event source determination.

A bit in the global status register is automatically set, when a bit in the respective status register is set (event based, not level based).

If a bit in the global status register is set, the user should read out the corresponding status register for the detailed information on the event source.

The bits in the global status flag register can be cleared without effect on the other status registers. Clearing a bit in any of the other status registers does not reset the corresponding bit in the global status register.

9.1.5.1 Register GSF

GSF RMAP: X Address: $1A_H$

Global status flags PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
INTMISS	**nu**	**R1VSxUV**	**OT**	**MON**	**SPI**	**MCU**	**SYS**
r	r	rw1c	rw1c	rw1c	rw1c	rw1c	rw1c

Field	Bits	Type	Description
INTMISS	7	r	**Interrupt timeout event** 0_H , no event 1_H , event occurred, cleared by hardware when all other flags in IF are cleared. Reset: 0_H
nu	6	r	**Not used**
R1VSxUV	5	rw1c	**Battery voltage undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
OT	4	rw1c	**Overtemperature or overcurrent monitoring event flag: *OTSF0*,*OTSF1*, *OCSF1*** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
MON	3	rw1c	**Voltage monitoring event flag: *MONSF0*, *MONSF1*, *MONSF2*** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
SPI	2	rw1c	**SPI event flag: *SPISF*** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag

SPI registers

(continued)

Field	Bits	Type	Description
			Reset: 0_H
MCU	1	rw1c	**MCU event flag: *MCUSF0-QM*,*MCUSF1-QM*** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
SYS	0	rw1c	**System event flag: *SYSSF0-QM*,*SYSSF1-QM*** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.2 Register SYSSF0

SYSSF0-QM RMAP: 1 Address: $1B_H$

System status flags – faults PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
BGFLT2	**BGFLT1**	**IOVDDOV**	**IOVDDUV**	**nu**			**FUSEERR**
rw1c	rw1c	rw1c	rw1c	r			rw1c

Field	Bits	Type	Description
BGFLT2	7	rw1c	**Bandgap fault event 2** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BGFLT1	6	rw1c	**Bandgap fault event 1** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
IOVDDOV	5	rw1c	**IOVDD overvoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
IOVDDUV	4	rw1c	**IOVDD undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	3:1	r	**Not used**
FUSEERR	0	rw1c	**Double bit error in fuse memory** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.3 Register SYSSF1

SYSSF1-QM RMAP: X Address: $1C_H$

System status flags – interrupts PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
BGWARN2	**BGWARN1**	**ENA_PWRUP**	**nu**	**SYNC**	**ENA**	**CFG2**	**CFG**
rw1c	rw1c	rw1c	r	rw1c	rw1c	rw1c	rw1c

Field	Bits	Type	Description
BGWARN2	7	rw1c	**Bandgap warning event 2** (VBG1+4%>VBG2) 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BGWARN1	6	rw1c	**Bandgap warning event 1** (VBG1-4%<VBG2) 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
ENA_PWRUP	5	rw1c	**Device wake-up condition** 0_H , device wake-up on a power-on-reset event, write 0 – no action 1_H , device wake-up on ENA event, write 1 to clear the flag Reset: 0_H
nu	4	r	**Not used**
SYNC	3	rw1c	**External clock synchronization fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
ENA	2	rw1c	**Enable interrupt event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
CFG2	1	rw1c	**Output voltage configuration change fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
CFG	0	rw1c	**Supervision functions configuration change fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.4 Register MCUSF0

MCUSF0-QM RMAP: 1 Address: $1D_H$

Microcontroller status flags 0 – faults PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
HARDRES	**SOFTRES**	**nu**		**WWDF**	**nu**		**INITF**
rw1c	rw1c	rw1c		rw1c	r		rw1c

Field	Bits	Type	Description
HARDRES	7	rw1c	**Hard reset event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
SOFTRES	6	rw1c	**Soft reset event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	5:4	rw1c	**Not used**
WWDF	3	rw1c	**Window watchdog fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	2:1	r	**Not used**
INITF	0	rw1c	**INIT timer error event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.5 Register MCUSF1

MCUSF1-QM RMAP: X Address: $1E_H$

Microcontroller status flags 1 – warnings PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
nu				**WWDMISS**	**nu**		
r				rw1c	r		

Field	Bits	Type	Description
nu	7:4	r	**Not used**
WWDMISS	3	rw1c	**Window watchdog missed trigger event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	2:0	r	**Not used**

9.1.5.6 Register SPISF

SPISF RMAP: X Address: $1F_H$

SPI status flags PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
nu	**B2VCTRL**	**DEVCTRL**	**LOCK**	**DUR**	**ADDR**	**LEN**	**PAR**
r	rw1c	rw1c	rw1c	rw1c	rw1c	rw1c	rw1c

Field	Bits	Type	Description
nu	7	r	**Not used**
B2VCTRL	6	rw1c	**SPI protocol B2VCTRL access error event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
DEVCTRL	5	rw1c	**SPI protocol DEVCTRL access error event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
LOCK	4	rw1c	**SPI protocol LOCK or UNLOCK access error event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
DUR	3	rw1c	**SPI duration error event** Chip select signal CS "low" for more than 2 ms 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
ADDR	2	rw1c	**SPI invalid address error event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
LEN	1	rw1c	**SPI frame length error event** Number of detected SPI clock cycles different than 16 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
PAR	0	rw1c	**SPI parity error event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.7 Register MONSF0

MONSF0 RMAP: 1 Address: 20_H

Voltage monitoring status flags 0 – short to ground PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
VM2STG	**VM1STG**	**nu**	**BOOST1STG**	**nu**		**BUCK2STG**	**BUCK1STG**
rw1c	rw1c	r	rw1c	r		rw1c	rw1c

Field	Bits	Type	Description
VM2STG	7	rw1c	**External voltage monitoring 2 short to ground event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
VM1STG	6	rw1c	**External voltage monitoring 1 short to ground event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	5	r	**Not used**
BOOST1STG	4	rw1c	**Boost1 short to ground event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	3:2	r	**Not used**
BUCK2STG	1	rw1c	**Buck2 short to ground event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BUCK1STG	0	rw1c	**Buck1 short to ground event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.8 Register MONSF1

MONSF1 RMAP: 1 Address: 21_H

Voltage monitoring status flags 1 – overvoltage PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
VM2OV	**VM1OV**	**nu**	**BOOST1OV**	**nu**		**BUCK2OV**	**BUCK1OV**
rw1c	rw1c	r	rw1c	r		rw1c	rw1c

Field	Bits	Type	Description
VM2OV	7	rw1c	**External voltage monitoring 2 overvoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
VM1OV	6	rw1c	**External voltage monitoring 1 overvoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	5	r	**Not used**
BOOST1OV	4	rw1c	**Boost1 overvoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	3:2	r	**Not used**
BUCK2OV	1	rw1c	**Buck2 overvoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BUCK1OV	0	rw1c	**Buck1 overvoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.9 Register MONSF2

MONSF2 RMAP: 1 Address: 22_H

Voltage monitoring status flags 2 – undervoltage PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
VM2UV	**VM1UV**	**nu**	**BOOST1UV**	**nu**		**BUCK2UV**	**BUCK1UV**
rw1c	rw1c	r	rw1c	r		rw1c	rw1c

Field	Bits	Type	Description
VM2UV	7	rw1c	**External voltage monitoring 2 undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
VM1UV	6	rw1c	**External voltage monitoring 1 undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	5	r	**Not used**
BOOST1UV	4	rw1c	**Boost1 undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	3:2	r	**Not used**
BUCK2UV	1	rw1c	**Buck2 undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BUCK1UV	0	rw1c	**Buck1 undervoltage event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.10 Register OTSF0

OTSF0 RMAP: 1 Address: 23_H

Overtemperature events 0 – faults PAGE: 0 Reset Value: 00_H

7	6	5	4	3	2	1	0
MONOT	**nu**					**BUCK2OT**	**BUCK1OT**
rw1c	r					rw1c	rw1c

Field	Bits	Type	Description
MONOT	7	rw1c	**Monitoring overtemperature fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	6:2	r	**Not used**
BUCK2OT	1	rw1c	**Buck2 overtemperature fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BUCK1OT	0	rw1c	**Buck1 overtemperature fault event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.11 Register OTSF1

OTSF1 RMAP: X Address: 24_H

Overtemperature flags 1 – warnings PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
MONOTW	**nu**					**BUCK2OTW**	**BUCK1OTW**
rw1c	r					rw1c	rw1c

Field	Bits	Type	Description
MONOTW	7	rw1c	**Monitoring overtemperature warning event** 0_H , no event, write 0 – no action 1_H , event detected – write 1 to clear flag Reset: 0_H
nu	6:2	r	**Not used**
BUCK2OTW	1	rw1c	**Buck2 overtemperature warning event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BUCK1OTW	0	rw1c	**Buck1 overtemperature warning event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.5.12 Register OCSF1

OCSF1 RMAP: X Address: 25_H

Overcurrent flags – warnings PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
nu			**BOOST1OCW**	**nu**		**BUCK2OCW**	**BUCK1OCW**
r			rw1c	r		rw1c	rw1c

Field	Bits	Type	Description
nu	7:5	r	**Not used**
BOOST1OCW	4	rw1c	**Boost1 overcurrent warning event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
nu	3:2	r	**Not used**
BUCK2OCW	1	rw1c	**Buck2 overcurrent warning event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H
BUCK1OCW	0	rw1c	**Buck1 overcurrent warning event** 0_H , no event, write 0 – no action 1_H , event occurred, write 1 to clear the flag Reset: 0_H

9.1.6 Device status information registers

The device status information registers reflect the current status of the device irrespective of the latched status information in the interrupt flag registers. Therefore, reading these registers reflects the current status of the device, for example the currently active power rails or the temperature warnings.

9.1.6.1 Register OTSTAT0

OTSTAT0 RMAP: X Address: 26_H

Overtemperature status 0 – warnings PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
MONOTW	**nu**					**BUCK2OTW**	**BUCK1OTW**
r	r					r	r

Field	Bits	Type	Description
MONOTW	7	r	**Monitoring overtemperature warning STATUS** 0_H , no overtemperature warning 1_H , overtemperature warning present Reset: 0_H
nu	6:2	r	**Not used**
BUCK2OTW	1	r	**Buck2 overtemperature warning STATUS** 0_H , no overtemperature warning 1_H , overtemperature warning present Reset: 0_H
BUCK1OTW	0	r	**Buck1 overtemperature warning STATUS** 0_H , no overtemperature warning 1_H , overtemperature warning present Reset: 0_H

9.1.6.2 Register VMONSTAT0

VMONSTAT0 RMAP: X Address: 27_H

Voltage monitoring PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
VM2OK	**VM1OK**	**R1VSxUV**	**BOOST1OK**	**SYNCOK**	**ENA**	**BUCK2OK**	**BUCK1OK**
r	r	r	r	r	r	r	r

Field	Bits	Type	Description
VM2OK	7	r	**External voltage monitoring 2 STATUS** 0_H , output rail disabled or not in total operation band 1_H , output rail enabled and in total operation band Reset: 0_H
VM1OK	6	r	**External voltage monitoring 1 STATUS** 0_H , output rail disabled or not in total operation band 1_H , output rail enabled and in total operation band Reset: 0_H
R1VSxUV	5	r	**Battery undervoltage STATUS** 0_H , battery voltage undervoltage not present. 1_H , battery voltage undervoltage present. Reset: 0_H
BOOST1OK	4	r	**Boost1 STATUS** 0_H , output rail disabled or not in total operation band 1_H , output rail enabled and in total operation band Reset: 0_H
SYNCOK	3	r	**External clock synchronization STATUS** 0_H , clock synchronization is not operating 1_H , clock synchronization is operating. Reset: 0_H
ENA	2	r	**Enable signal level** 0_H , enable signal is "low" 1_H , enable signal is "high" Reset: 0_H
BUCK2OK	1	r	**Buck2 STATUS** 0_H , output rail disabled or not in total operation band 1_H , output rail enabled and in total operation band Reset: 0_H
BUCK1OK	0	r	**Buck1 STATUS** 0_H , output rail disabled or not in total operation band 1_H , output rail enabled and in total operation band Reset: 0_H

9.1.6.3 Register DEVSTAT

DEVSTAT RMAP: X Address: 28_H

Device state information PAGE: 1 Reset Value: 00_H

7	6	5	4	3	2	1	0
VM2EN	**VM1EN**	**BOOST1EN**	**BUCK2EN**	**nu**	**STATE**		
r	r	r	r	r	r		

Field	Bits	Type	Description
VM2EN	7	r	**External voltage monitoring 2 enable STATUS** 0_H , voltage is disabled 1_H , voltage is enabled Reset: 0_H
VM1EN	6	r	**External voltage monitoring 1 enable STATUS** 0_H , voltage is disabled 1_H , voltage is enabled Reset: 0_H
BOOST1EN	5	r	**Boost 1 enable STATUS** 0_H , voltage is disabled 1_H , voltage is enabled Reset: 0_H
BUCK2EN	4	r	**Buck 2 enable STATUS** 0_H , voltage is disabled 1_H , voltage is enabled Reset: 0_H
nu	3	r	**Not used**
STATE	2:0	r	**Device state** 0_H reserved 1_H , ACTIVE state 2_H reserved 3_H reserved 4_H reserved 5_H reserved 6_H reserved 7_H reserved Reset: 0_H

9.1.6.4 Register PROTSTAT

PROTSTAT RMAP: X Address: 29_H

Protection status information PAGE: 2 Reset Value: 01_H

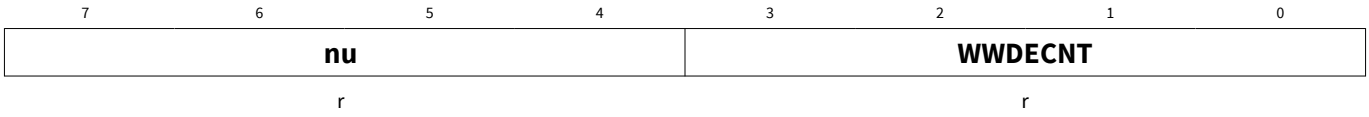
7	6	5	4	3	2	1	0
KEY4OK	**KEY3OK**	**KEY2OK**	**KEY1OK**	**nu**			**LOCK**
r	r	r	r	r			r

Field	Bits	Type	Description
KEY4OK	7	r	**Fourth protection key valid STATUS** 0_H , key not valid 1_H , key valid Reset: 0_H
KEY3OK	6	r	**Third protection key valid STATUS** 0_H , key not valid 1_H , key valid Reset: 0_H
KEY2OK	5	r	**Second protection key valid STATUS** 0_H , key not valid 1_H , key valid Reset: 0_H
KEY1OK	4	r	**First protection key valid STATUS** 0_H , key not valid 1_H , key valid Reset: 0_H
nu	3:1	r	**Not used**
LOCK	0	r	**Lock STATUS** 0_H , access to protected registers is unlocked. 1_H , access to protected registers is locked. Reset: 0_H

9.1.6.5 Register WWDSTAT

WWDSTAT RMAP: X Address: $2A_H$

Window watchdog status information PAGE: 2 Reset Value: 00_H



Field	Bits	Type	Description
nu	7:4	r	**Not used**
WWDECNT	3:0	r	**Window watchdog error counter level** 0_H 0 1_H 1 ... F_H 15 Reset: 0_H

9.1.6.6 Register MPSSTAT0

MPSSTAT0

Microcontroller programming support status information

RMAP: X
PAGE: 1

Address: 37_H
Reset Value: 03_H

7	6	5	4	3	2	1	0
nu				**MPSSTAT**			
r				r			

Field	Bits	Type	Description
nu	7:4	r	**Not used**
MPSSTAT	3:0	r	**MPS STATUS** 3_H , device in operating mode 6_H , device in programming mode 9_H , device in test mode (production test mode, read-back only) Reset: 3_H

9.1.6.7 Register B2VSTAT

B2VSTAT RMAP: X Address: 39_H

Buck2 output voltage status PAGE: 1 Reset Value: 02_H

7	6	5	4	3	2	1	0
BUCK2VOUTC				**BUCK2VOUTF**			
r				r			

Field	Bits	Type	Description
BUCK2VOUTC	7:4	r	**Buck2 output voltage setting coarse resolution STATUS** 0_H , Range 0.9 – 1.3 V. Fine resolution is evaluated. 1_H , 1.5 V 2_H , 1.8 V 3_H , 2.45 V 4_H , 3.3 V Reset: 0_H
BUCK2VOUTF	3:0	r	**Buck2 output voltage setting fine resolution STATUS** 0_H , 1.30 V 1_H , 1.20 V 2_H , 1.25 V 3_H , 1.15 V 4_H , 1.10 V 5_H , 1.00 V 6_H , 1.05 V 7_H , 0.95 V 8_H , 0.90 V Reset: 2_H

9.1.7 Device information registers

9.1.7.1 Register HWDECT0

HWDECT0 RMAP: X Address: $3B_H$

Hardware option information PAGE: 1 Reset Value: $D3_H$

7	6	5	4	3	2	1	0
VM2AVA	**VM1AVA**	**nu**	**BOOST1AVA**	**nu**		**BUCK2AVA**	**FRE**
r	r	r	r	r		r	r

Field	Bits	Type	Description
VM2AVA	7	r	**External voltage monitoring 2 automatic use detection** 0_H , VM2 is not used in this application. 1_H , VM2 is used in this application. Reset: 1_H
VM1AVA	6	r	**External voltage monitoring 1 automatic use detection** 0_H , VM1 is not used in this application. 1_H , VM1 is used in this application. Reset: 1_H
nu	5	r	**Not used**
BOOST1AVA	4	r	**Boost1 automatic use detection** 0_H , Boost1 is not used in this application. 1_H , Boost1 is used in this application. Reset: 1_H
nu	3:2	r	**Not used**
BUCK2AVA	1	r	**Buck2 automatic use detection** 0_H , Buck2 is not used in this application. 1_H , Buck2 is used in this application. Reset: 1_H
FRE	0	r	**Frequency selection information** 0_H , LF frequency setting 1_H , HF frequency setting Reset: 1_H

9.1.7.2 Register DEVID

DEVID RMAP: X Address: $3C_H$

Device identification PAGE: 1 Reset Value: 30_H

7	6	5	4	3	2	1	0
DEVTYPE							
r							

Field	Bits	Type	Description
DEVTYPE	7:0	r	**Device family** 30_H , TLF30681 device Reset: 30_H

10 Application information

Note: The following information is given as an example for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.

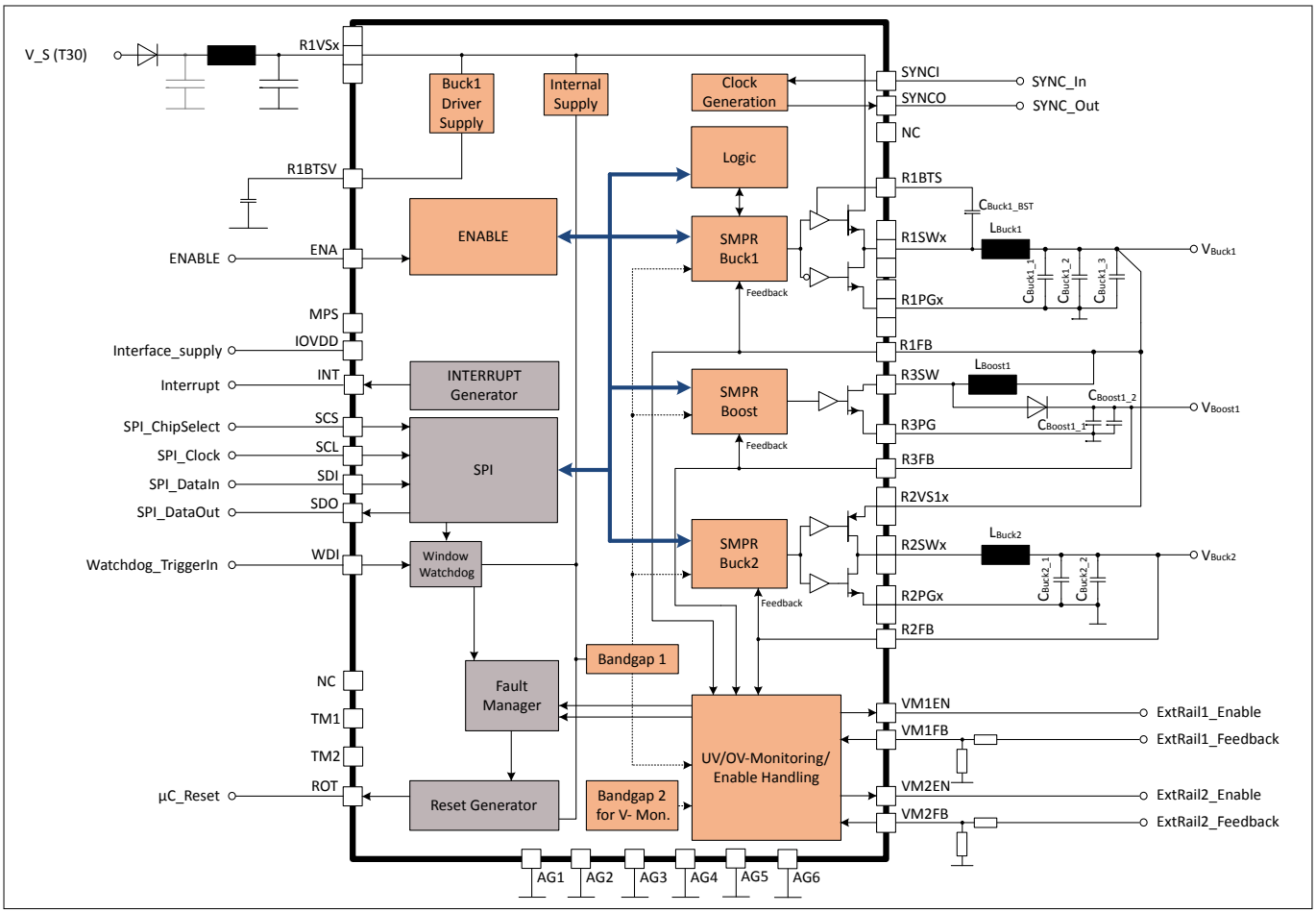


Figure 24 Application diagram

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

Table 30 Recommended values for the passive components in *Figure 24*

Name	Value (typical)	Comments
L_{Buck1}	3.3 µH	Buck1 inductor: Use an inductor with a saturation current above the Buck1 overcurrent protection threshold $I_{R1,OCP}$.
C_{Buck1_1}	33 µF	Buck1 output capacitor 1: Use a ceramic capacitor in X7R material with a voltage rating of 6.3 V or higher. Place this capacitor close to the R2VSx input of Buck2 and connect it between the R2VSx and R2PGx pins directly.

Table 30 Recommended values for the passive components in *Figure 24* (continued)

Name	Value (typical)	Comments
C_{Buck1_2}, C_{Buck1_3}	33 µF	Buck1 output capacitors 2 and 3: Use a ceramic capacitor in X7R material with a voltage rating of 6.3 V or higher.
C_{Buck1_BST}	100 nF	Buck1 bootstrap capacitor: Use a ceramic capacitor in X7R material with a voltage rating of 16 V or higher.
L_{Buck2}	1.5 µH	Buck2 inductor: Use an inductor with a saturation current above the Buck2 overcurrent protection threshold $I_{R2,OCP}$.
C_{Buck2_1}, C_{Buck2_2},	33 µF	Buck2 output capacitors 1 to 2: Use a ceramic capacitor in X7R material with a voltage rating of 6.3 V or higher.
L_{Boost1}	6.8 µH	Boost1 inductor: Use an inductor with a saturation current above the Boost1 overcurrent protection threshold $I_{R3,OCP}$.
C_{Boost1_1}	100 nF	Boost1 output capacitor 1: Use a ceramic capacitor in X7R material with a voltage rating of 10 V or higher.
C_{Boost1_2}	10 µF	Boost1 output capacitor 2: Use a ceramic capacitor in X7R material with a voltage rating of 10 V or higher.

For additional supportive documentation or further information please contact ***http://www.infineon.com/***.

11 Package information

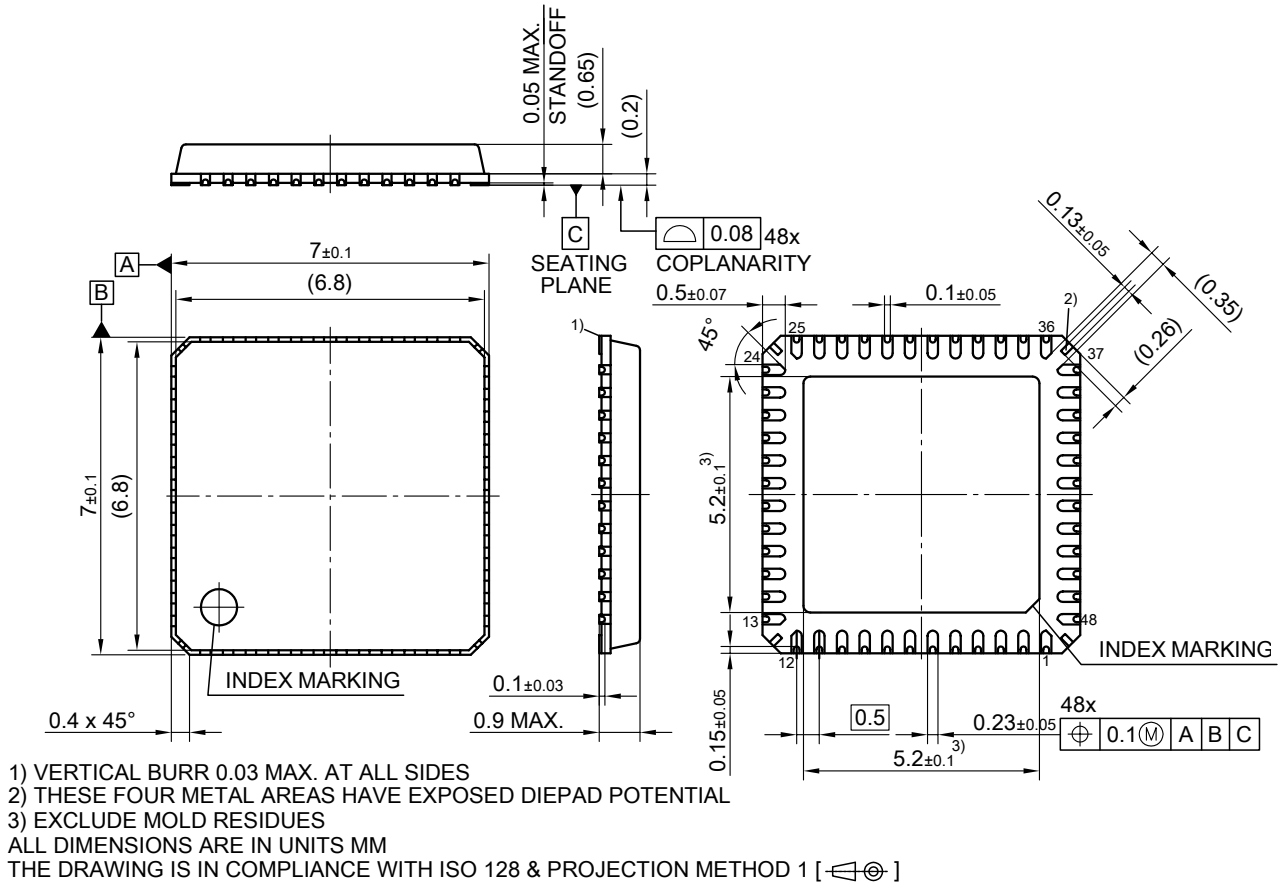


Figure 25 PG-VQFN-48

Green Product (RoHS compliant)

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

Information on alternative packages

Please visit ***www.infineon.com/packages***.

Revision history

Revision	Date	Changes
1.0	2020-04-08	Datasheet created.

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