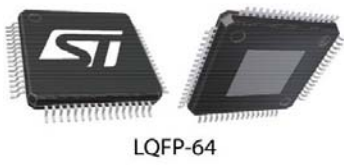
L99DZ200G

Automotive front door device with LIN and CAN providing dual H-bridge driving

Datasheet - production data



Features

- AEC-Q100 qualified
- 2 configurable half bridges for 7.5 A load (R_{ON} = 150 mΩ) or 3 A load (R_{ON} = 300 mΩ)
- 2 half bridges for 0.5 A load (R_{ON} = 2000 mΩ)
- 1 configurable high-side driver for up to 1.5 A (R_{ON} = 500 mΩ) or 0.35 A (R_{ON} = 1600 mΩ) load
- 1 configurable high-side driver for 0.7 A (R_{ON} = 800 mΩ) or 0.35 A (R_{ON} = 1600 mΩ) load
- 3 configurable high-side drivers for 0.15 A/0.35 A (R_{ON} =2 Ω)
- 1 configurable high-side driver for 0.25 A/0.5 A (R_{ON} = 2 Ω) to supply EC Glass MOSFET
- 1 configurable P-channel high-side drivers for 0.15 A/0.25 A (R_{ON} = 5 Ω)
- Internal 10-bit PWM timer for each stand-alone high-side driver
- Buffered supply for voltage regulators and 1 high-side driver (OUT15 P-channel) to supply e.g. external contacts
- Programmable soft-start function to drive loads with higher inrush currents as current limitation value for OUT1-6 (i.e. motors) and OUT7, OUT8 (i.e. bulbs) with thermal expiration feature
- Flexible HS drivers (OUT7, OUT8 and OUT9) suitable to drive external LED modules with high input capacitance
- All the embedded outputs come with protection and supervision features:
  - Current Monitor (high-side only)
  - Open-load and Overcurrent
  - Thermal warning and Thermal shutdown
- 2 fully protected drivers for external MOSFETs in H-bridge configuration, dual Half bridge configuration and combined configuration to drive 3 motors
- Fully protected driver for external high-side MOSFET
- Control block for electro-chromic element
- One 5 V voltage regulators for microcontroller supply
- One 5 V voltage tracker for peripheral supply
- Programmable reset generator for power-on and under voltage
- Configurable window watchdog
- LIN 2.2a compliant (SAEJ2602 compatible and SAE J2962-1 compliant) transceiver
- Advanced high speed CAN transceiver (ISO 11898-2:2003 /-5:2007 and SAE J2284 & SAE J2962-2 compliant) with local failure and bus failure; HS-CAN Transceiver Conformance Test according to «Interoperability test specification for high-speed CAN transceiver or equivalent devices IOPT.CAN v02d00»
- Separated (Isolated) fail-safe block with 2 LS (R_{ON} = 1 Ω) to pull down the gates of the external HS MOSFETs
- Thermal clusters
- A/D conversion of supply voltages and internal temperature sensors
- Embedded and programmable VS duty cycle adjustment for LED driver outputs
- Generator Mode for Power Trunk/Tailgate applications

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1 Description

The L99DZ200G is a door zone systems IC providing electronic control modules with enhanced power management power supply functionality, including various standby modes, as well as LIN and HS CAN physical communication layers.

The two low-drop voltage regulators of the device supply the system microcontroller and external peripheral loads such as sensors and provide enhanced system standby functionality with programmable local and remote wake-up capability. In addition 5 high-side drivers to supply LEDs, 2 high-side drivers to supply bulbs increase the system integration level.

Three High Side drivers can be configured to support the so-called Constant Current mode conceived to supply external LED modules with huge decoupling capacitors.

Up to 3 DC motors and 8 external MOS transistors (4 for each of the 2 H-bridges) in H-bridge configuration can be driven. An additional gate drive can control an external MOSFET in high-side configuration to supply a resistive load connected to GND (e.g. mirror heater). An electro-chromic mirror glass can be controlled using the integrated SPI-driven module in conjunction with an external MOS transistor. All outputs are SC protected and implement an open-load diagnosis.

The ST standard SPI interface (4.0) allows control and diagnosis of the device and enables generic software development.

2 Block diagram and pin descriptions

Figure 1. Block diagram

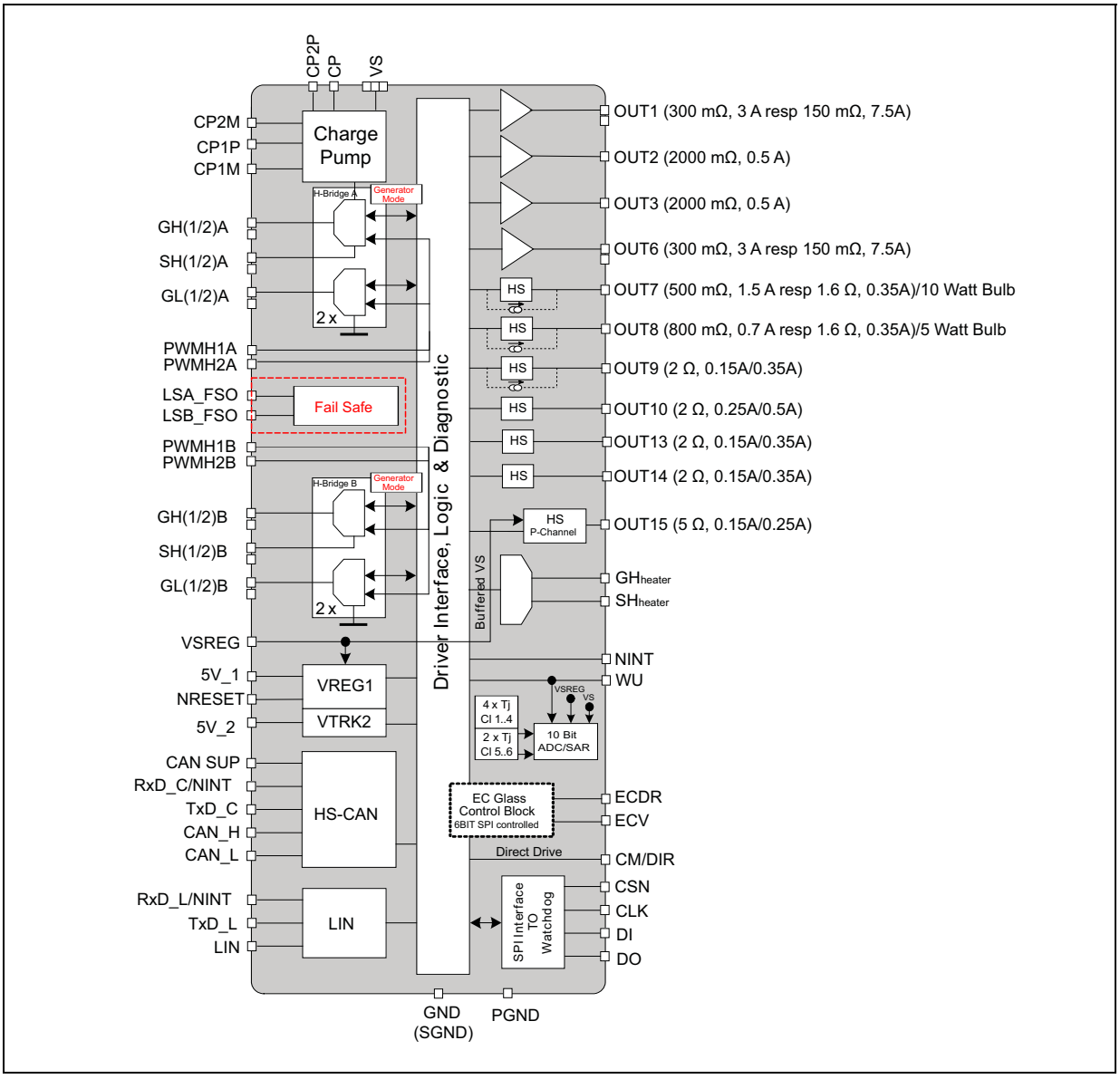


Table 1. Pin definition and functions

Pin	Symbol	Function
1	WU	Wake-up Input: Input pin for static or cyclic monitoring of external contacts or Vbat measurement (configurable via SPI)
2	GL1B	Gate driver for PowerMOS low-side switch in half-bridge 1 (H-bridge B)
3	SH1B	Source of high-side switch in half-bridge 1 (H-bridge B)
4	GH1B	Gate driver for PowerMOS high-side switch in half-bridge 1 (H-bridge B)

Table 1. Pin definition and functions (continued)

Pin	Symbol	Function
5	GH2B	Gate driver for PowerMOS high-side switch in half-bridge 2 (H-bridge B)
6	SH2B	Source of high-side switch in half-bridge 2 (H-bridge B)
7	GL2B	Gate driver for PowerMOS low-side switch in half-bridge 2 (H-bridge B)
8	CP2M	Charge pump pin for capacitor 2, negative side
9	CP2P	Charge pump pin for capacitor 2, positive side
10	CP	Charge pump output
11	CP1P	Charge pump pin for capacitor 1, positive side
12	CP1M	Charge pump pin for capacitor 1, negative side
13	GHheater	Gate driver for external power N-Channel MOSFET in high-side configuration to control the heater
14	SHheater	Source of high-side MOSFET to control the heater
15	LSA_FSO	Fail Safe low-side switch (Active low)
16	LSB_FSO	Fail Safe low-side switch (Active low)
17	VS	Power supply voltage for power stage outputs (external reverse battery protection required). For this input a ceramic capacitor as close as possible to GND is recommended. Important: for the capability of driving the full current at the outputs, all pins of VS must be externally connected!
18	VS; 2nd pin	Current capability (pin description see above)
19	OUT13	High-side-driver output to drive LEDs
20	OUT10	High-side-driver-output; Important: Beside the bits OUT10_x (CR 5) this output can be switched on setting the ECON bit for electro-chrome control mode with higher priority.
21	OUT9	High-side-driver output to drive LEDs; it can be configured to work in Constant Current Mode.
22	OUT7	High-side-driver output to drive LEDs or a 10 Watt bulb (programmable Rdson); it can be configured to work in Constant Current Mode.
23	OUT6	Half-bridge outputs: the output is built by a high-side and a low-side switch which are internally connected. The output stage of both switches is a power DMOS transistor. Each driver has an internal parasitic reverse diode (bulk-drain-diode: high-side driver from output to VS, low-side driver from GND to output)
24	OUT6; 2nd pin	Current capability (pin description see above)
25	OUT1	Half-bridge outputs: the output is built by a high-side and a low-side switch which are internally connected. The output stage of both switches is a power DMOS transistor. Each driver has an internal parasitic reverse diode (bulk-drain-diode: high-side driver from output to VS, low-side driver from GND to output)
26	OUT1; 2nd pin	Current capability (pin description see above)
27	OUT8	High-side-driver output to drive LEDs or a 5 Watt bulb (programmable R_{dson}); it can be configured to work in Constant Current Mode.

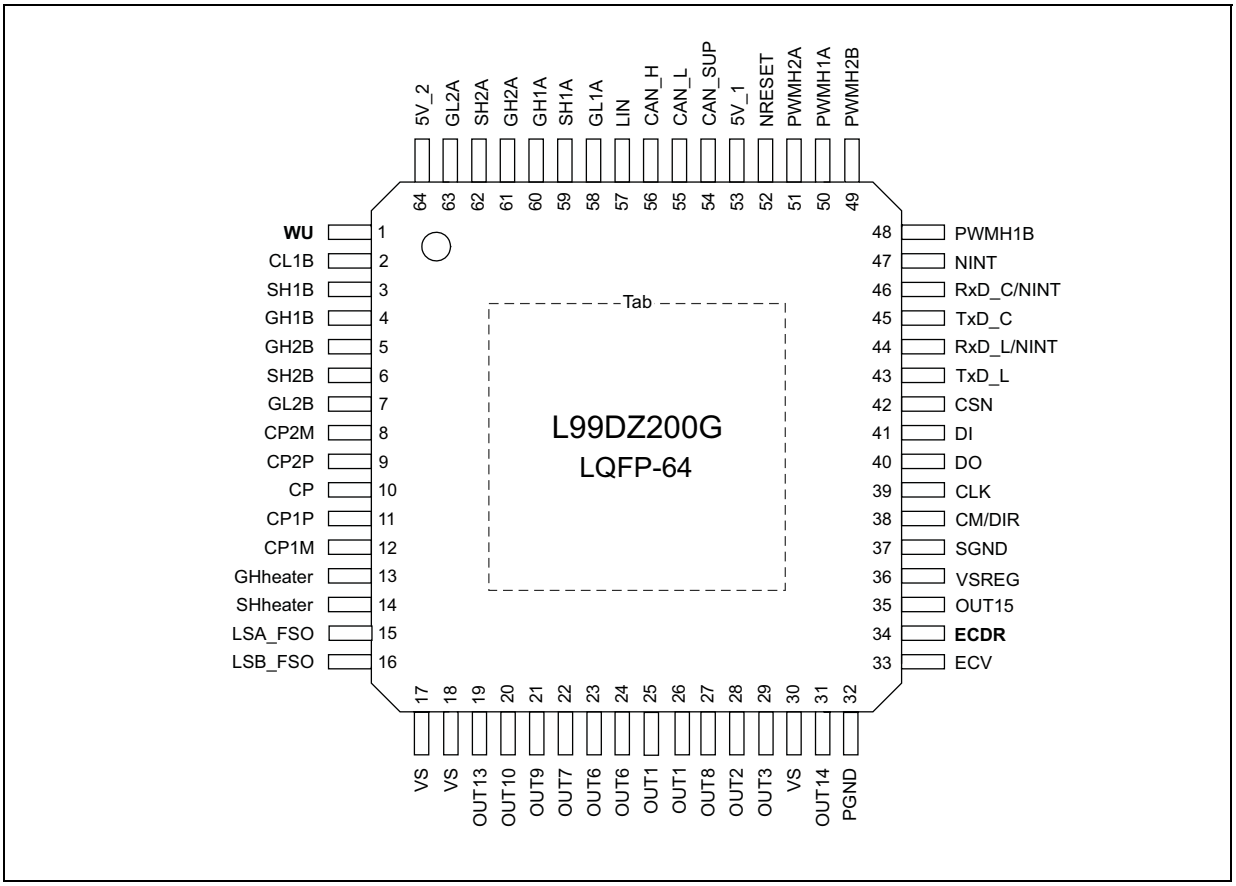
Table 1. Pin definition and functions (continued)

Pin	Symbol	Function
28	OUT2	Half-bridge outputs: the output is built by a high-side and a low-side switch which are internally connected. The output stage of both switches is a power DMOS transistor. Each driver has an internal parasitic reverse diode (bulk-drain-diode: high-side driver from output to VS, low-side driver from GND to output)
29	OUT3	Half-bridge outputs: the output is built by a high-side and a low-side switch which are internally connected. The output stage of both switches is a power DMOS transistor. Each driver has an internal parasitic reverse diode (bulk-drain-diode: high-side driver from output to V_S, low-side driver from GND to output)
30	VS; 3rd pin	Current capability (for the pin description see above)
31	OUT14	High-side-driver output to drive LEDs
32	PGND	Power Ground
33	ECV	ECV: using the device in EC control mode this pin is used as voltage monitor input. For fast discharge an additional low-side-switch is implemented
34	ECDR	ECDR: using the device in EC control mode this pin is used to control the gate of an external N-Channel MOSFET
35	OUT15	P-Channel High-side-driver output to drive LEDs or to supply contacts even in standby mode; supplied by V_{SREG}
36	V_{SREG}	Power supply voltage to supply the internal voltage regulator, the internal voltage tracker and OUT15 (external reverse battery protection required / Diode) for this input a ceramic capacitor as close as possible to GND and an electrolytic back up capacitor is recommended.
37	SGND	Signal Ground
38	CM / DIR	Current monitor output / DIR input: depending on the selected multiplexer bits *CM_SEL_x* (*CR 7*) of the Control Register, this output sources an image of the instant current; through the corresponding high-side driver with a fixed ratio. This pin is bidirectional. The Microcontroller can overdrive the current monitor signal to provide the Direct Drive Input.
39	CLK	SPI: serial clock input
40	DO	SPI: serial data output (push pull output stage)
41	DI	SPI: serial data input
42	CSN	SPI: chip select not input
43	TxD_L	LIN Transmit data input
44	RxD_L/NINT	RxD_L -> LIN receive data output; NINT -> indicates local/remote wake-up events (push pull output stage)
45	TxD_C	CAN transmit data input
46	RxD_C/NINT	CAN receive data output; NINT -> indicates local/remote wake-up events (push pull output stage)
47	NINT	Interrupt output (low active; push-pull output stage) to indicate V_{SREG} early warning (Active mode); indicates wake-up events from V1_Standby mode
48	PWMH1B	PWMH1 input for H-bridge B: this input signal can be used to control the H-bridge B Gate Drivers.

Table 1. Pin definition and functions (continued)

Pin	Symbol	Function
49	PWMH2B	PWMH2 input for H-bridge B: this input signal can be used to control the H-bridge B Gate Drivers.
50	PWMH1A	PWMH1 input for H-bridge A: this input signal can be used to control the H-bridge A Gate Drivers.
51	PWMH2A	PWMH2 input for H-bridge A: this input signal can be used to control the H-bridge A Gate Drivers.
52	NRESET	NReset output to microcontroller; (reset state = LOW) (Low-side switch with drain connected to the output pin and internal pull up resistance to 5V_1)
53	5V_1	Voltage regulator 1 output: 5 V supply e.g. microcontroller, CAN transceiver
54	CAN_SUP	CAN supply input; to allow external CAN supply from V1 regulator
55	CAN_L	CAN low level voltage I/O
56	CAN_H	CAN high level voltage I/O
57	LIN	LIN bus line
58	GL1A	Gate driver for PowerMOS low-side switch in half-bridge 1 (H-bridge A)
59	SH1A	Source of high-side switch in half-bridge 1 (H-bridge A)
60	GH1A	Gate driver for PowerMOS high-side switch in half-bridge 1 (H-bridge A)
61	GH2A	Gate driver for PowerMOS high-side switch in half-bridge 2 (H-bridge A)
62	SH2A	Source of high-side switch in half-bridge 2 (H-bridge A)
63	GL2A	Gate driver for PowerMOS low-side switch in half-bridge 2 (H-bridge A)
64	5V_2	Voltage Regulator or Tracker 2 output: 5 V supply for external loads (potentiometer, sensors). 5V_2 pin is protected against short to ground or to battery
TAB		Connect to ground

Figure 2. Pin Connection (top view)



3 Electrical specifications

3.1 Absolute maximum ratings

Stressing the device above the rating listed in *Table 2* may cause permanent damage to the device. These are stress ratings only and operation of the device at these or any other conditions above those indicated in the operating sections of this specification is not implied. Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability.

Table 2. Absolute maximum ratings

Symbol	Parameter / Test condition	Value [DC Voltage]	Unit
V_S, V_{SREG}	DC supply voltage / “jump start”	-0.3 to +28	V
	Load dump	-0.3 to +40	V
5V_1	Stabilized supply voltage, logic supply	-0.3 to 6.5 V1 < V_{SREG}	V
5V_2(1)	Stabilized supply voltage	-0.3 to +28(2)	V
V_{DI} , V_{CLK},V_{CSN},V_{DO}, $V_{RXDL/NINT}$, V_{RXDC}, V_{NRESET}, V_{CM}, V_{DIR}, V_{PWMH}, V_{INT}	Logic input / output voltage range	-0.3 to V1+0.3	V
V_{TXDC}, V_{TXDL}	Multi-Level Inputs	-0.3 to 40	V
V_{LSA_FSO}, V_{LSB_FSO}	Output voltage range of Fail-Safe Low-side Switches	-0.3 to 35	V
V_{WU}	DC Wake up input voltage / “jump start”	-0.3 to +28	V
	Load dump	-0.3 to +40	V
V_{LIN}	LIN bus I/O voltage range	-20 to +40	V
I_{Input}(3)	Current injection into V_S related input pins	20	mA
I_{OUT_INJ}(3)	Current injection into V_S related outputs	20	mA
V_{CANSUP}(4)	CAN supply	-0.3 to +5.25	V
V_{CANH}, V_{CANL}	CAN bus I/O voltage range	-27 to +40	V
V_{CANH} - V_{CANL}	Differential CAN-Bus Voltage	-5 to +10	V
V_{OUTn}, V_{ECDR}, V_{ECV}	Output voltage (n = 1,2,3,6,7,8,9,10,13,14,15)	-0.3 to V_S+0.3	V
V_{GH1}, V_{GH2} (V_{GHx})	High Voltage Signal Pins	V_{SHx}-0.3 to V_{SHx}+13; V_{CP}+0.3	V
V_{GL1}, V_{GL2} (V_{GLx})	High Voltage Signal Pins	-0.3 to 13;	V
V_{SH1}, V_{SH2} (V_{SHx})	High Voltage Signal Pins	-1 to V_S+0.3	V
	High Voltage Signal Pins; single pulse with t_{max} = 200 ns	-5 to 40	V
V_{CP1P}	High Voltage Signal Pins	V_S-0.3 to V_S+14	V
V_{CP2P}	High Voltage Signal Pins	V_S-0.6 to V_S+14	V
V_{CP1M}, V_{CP2M}	High Voltage Signal Pins	-0.3 to V_S+0.3	V
V_{CP}	High Voltage Signal Pin $V_S \leq 26$ V	V_S-0.3 to V_S+14	V

Table 2. Absolute maximum ratings (continued)

Symbol	Parameter / Test condition	Value [DC Voltage]	Unit
	High Voltage Signal Pin V_S > 26 V	V_S-0.3 to +40	V
V_{GH_heater}		$V_{Sheater}$-0.3 to $V_{Sheater}$+13; V_{CP}+0.3	V
V_{SH_heater}		-0.3 to Vs+0.3	V
IOUT2, IOUT3, IOUT8, IOUT9, IOUT10, IOUT13, IOUT14	Output current(2)	±2.5	A
IOUT7		±5	A
IECV, IOUT15		±1.25	A
IOUT1,6		±10	A
I_{VScum}	Maximum cumulated current at V_S drawn by OUT1(2)	10	A
I_{VScum}	Maximum cumulated current at V_S drawn by OUT6(2)	10	A
I_{VScum}	Maximum cumulated current at V_S drawn by OUT3 & OUT14(2)	2.5	A
I_{VScum}	Maximum cumulated current at V_S drawn by OUT2 & OUT8(2)	2.5	A
I_{VScum}	Maximum cumulated current at V_S drawn by OUT7(2)	5	A
I_{VScum}	Maximum cumulated current at V_S drawn by OUT9, OUT10, OUT13 and CP	2.5	A
I_{VSREG}	Maximum current at V_{SREG} pin(2) (5V_1. 5V_2) & OUT15	±1.25	A
$I_{PGNDcum}$	Maximum cumulated current at PGND drawn by OUT1(2)	10	A
$I_{PGNDcum}$	Maximum cumulated current at PGND drawn by OUT6(2)	10	A
$I_{PGNDcum}$	Maximum cumulated current at PGND drawn by OUT2(2)	2.5	A
$I_{PGNDcum}$	Maximum cumulated current at PGND drawn by OUT3 & ECV(2)	2.5	A
I_{SGND}	Maximum current at SGND(2)	±1.25	A
GND pins	PGND versus SGND	-0.3 to 0.3	V

1. 5V_2 is robust against SC to 28 V only in case V_{SREG} is supplied.
2. Values for the absolute maximum DC current through the bond wires. This value does not consider maximum power dissipation or other limits.
3. Guaranteed by design.
4. When CAN_SUP pin is directly connected to the 5V_1 pin, the relevant absolute maximum rating becomes [-0.3V, 5.25V] for both the connected pins.

Note: All maximum ratings are absolute ratings. Leaving the limitation of any of these values may cause an irreversible damage of the integrated circuit!

Note: Loss of ground or ground shift with externally grounded loads: ESD structures are configured for nominal currents only. If external loads are connected to different grounds, the current load must be limited to this nominal current.

3.2 ESD protection

Table 3. ESD protection

Parameter	Value	Unit
All pins(1)	+/-2	kV
All power output pins(2): OUT1-15, ECV	+/-4	kV
LIN	+/-25(3)	kV
	+/-15(4)	
	+/-8(2)	
	+/-8(5)	
	+/-6(6)	
CAN_H, CAN_L	+/-15(7)	kV
	+/-8 (2)	kV
	+/-6(6)	
All pins(8)	+/-500	V
Corner pins(8)	+/-750	V

1. HBM (human body model, 100pF, 1.5 k) according to AEC-Q100-002.
2. HBM with all none zapped pins grounded.
3. Air discharge for LIN (according to SAE J2962-1, July 2019) C = 150pF, R = 2kΩ and ST ESDLIN1524BJ.
4. Air discharge for LIN (according to SAE J2962-1, July 2019) C = 330pF, R = 2kΩ and ST ESDLIN1524BJ.
5. Indirect ESD Test according to IEC 61000-4-2 (150pF, 330Ω) and 'Hardware Requirements for LIN, CAN and Flexray Interfaces in Automotive Applications' (version 1.3, May 2012).
6. Direct ESD Test according to IEC 61000-4-2 (150pF, 330Ω) and 'Hardware Requirements for LIN, CAN and Flexray Interfaces in Automotive Applications' (version 1.3, May 2012).
7. Air discharge for CAN (according to SAE J2962-2, July 2019) C = 330pF, R = 2kΩ and ST ESDCAN04-2BWY.
8. Charged Device Model according to AEC-Q100-011.

3.3 Thermal data

Table 4. Operating junction temperature

Symbol	Parameter	Value	Unit
T_j	Operating junction temperature	-40 to 175	°C

All parameters are guaranteed in the junction temperature range -40 to 150°C (unless otherwise specified); the device is still operative and functional at higher temperatures (up to 175°C).

Note: Parameters limits at higher junction temperatures than 150°C may change with respect to what is specified as per the standard temperature range.

Note: Device functionality at high junction temperature is guaranteed by characterization.

Table 5. Temperature Warning and Thermal Shutdown

Item(1)	Symbol	Parameter		Min.	Typ.	Max.	Unit
F.025	T_W	Thermal warning threshold	T_j (2)	140	150	160	°C
F.026	T_{SD1}	Thermal shutdown junction temperature 1	T_j (2) Cluster 1-4	165	175	185	°C
F.027			T_j (2) Cluster 5-6	165	175	193	
F.028	T_{SD2}	Thermal shutdown junction temperature 2	T_j (2)	175	185	198	°C
F.029	$T_{SD12hys}$		Hysteresis		5		°C
F.030	T_{jtft} (3)	Thermal warning / shutdown filter time			32		µs

1. The Item numbering is described in *Section 3.4: Electrical characteristics*.
2. Non-overlapping.
3. Tested by scan.

3.3.1 LQFP64 thermal data

L99DZ200G embeds a multitude of junctions (i.e. Outputs based on a Power MOSFET stage) housed in a relatively small piece of silicon. The devices contain, among all the described features, 4 Half-bridges (8 N-Channel PowerMOS), 7 high-sides, two voltage regulators (one of which can work as voltage tracker); all the other derivatives, even if smaller than the family super set device, still contain a significant number of junctions.

For this reason, using the Thermal Impedance of a single junction (i.e. voltage regulator or major power dissipation contributor) does not allow to predict thermal behavior of the whole device and therefore it is not possible to assess if a device is thermally suitable for a given activation profile and loads characteristics.

Thermal information is provided as temperature reading by different clusters placed close to the most dissipative junctions.

Some representative and realistic worst-case thermal profiles are described in the below paragraph.

The following measurement methods can be easily implemented, by the final user, for a specific activation profile.

L99DZ200G thermal profiles

Activation Profile

Battery Voltage: 16 V, ambient temperature start: 85°C

DC activation

- V1 charged with 70 mA (DC activation)
- V2 charged with 30 mA (DC activation)
- OUT7: 1 x10W bulb (DC activation)
- OUT8: 1 x 5W bulb (DC activation)
- OUT13: 300 Ω resistor (DC activation
- OUT14: 300 Ω resistor (DC activation)

Cyclic activation

- OUT1 – OUT6: 5.6 Ω resistor placed across those outputs
  - 2 activations of Fold/Unfold. (3s ON; 1s OFF; 2x)
  - OUT1 and OUT6 configured with the lowest Rdson

Test execution:

Once thermal equilibrium is reached with all DC load active, the “Cyclic Activation” sequence is applied.

Figure 3. Activation profile

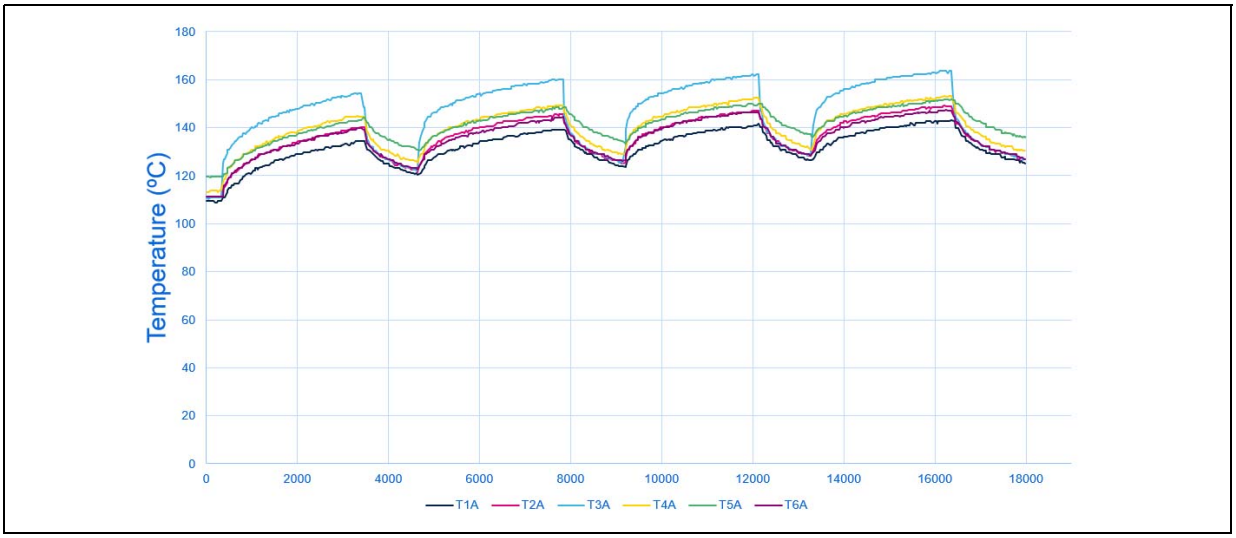


Figure 4. Activation profile (first cycle)

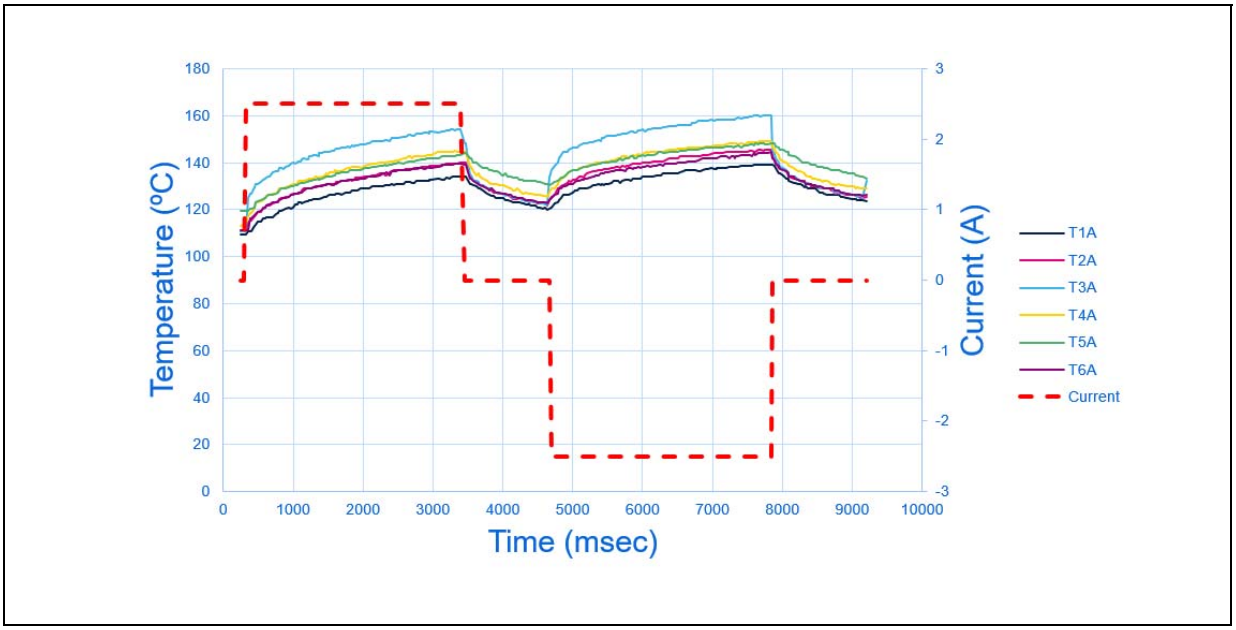
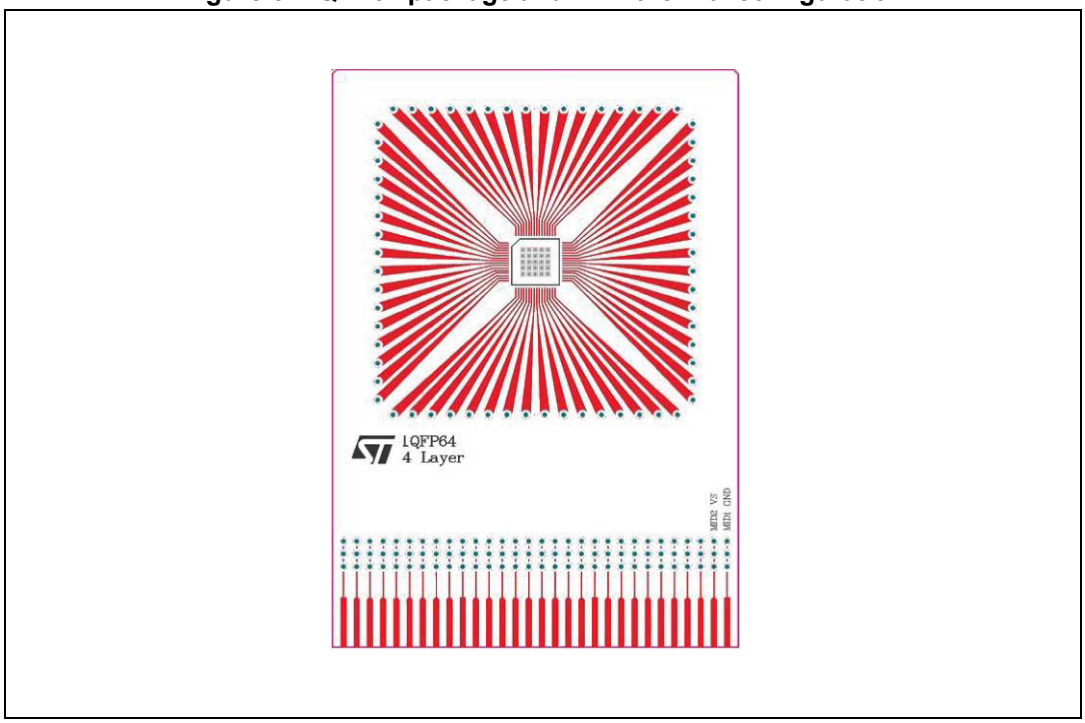


Figure 5. LQFP64 package and PCB thermal configuration



Note: Layout condition for Thermal Characterization (board finishing thickness 1.5 mm +/- 10%, board four layers, board dimension 77 mm x 114 mm, board material FR4, Cu thickness 0,070 mm for outer layers, 0.0035 mm for inner layers, thermal vias separation 1.2 mm).

3.4 Electrical characteristics

For an efficient and easy tracking, numbering has been added to each electrical parameter.

Device features are split into categories, see *Table 6*, and each of them is represented by a letter (A, B, C, etc.); all parameters will be completely identified by a letter and a three digit number (e.g. B.125, C.096…) for their whole lifetime.

New inserted parameters will continue with the numbering of the related category, no matter where they are placed.

To facilitate insertion, the last number inserted for each category is also reported in *Table 6*.

Table 6. Electrical parameters numbering

Category	Parameters numbering	Last Inserted
Analog I/O	A.xxx	A.188
Digital I/O	B.xxx	B.034
Voltage Regulators	C.xxx	C.056
Outputs	D.xxx	D.093
Transceivers	E.xxx	E.092
Others	F.xxx	F.030

Due to these rules and taking into account that deleted parameter numbers will be no more reassigned, numbering inside each category may be not sequential.

3.4.1 Supply and supply monitoring

All SPI communication, logic and oscillator parameters are working down to V_{SREG} = 3.5 V and parameters are as specified in the following chapters (guaranteed by design).

- SPI thresholds
- Oscillator frequency (delay times correctly elapsed)
- Internal register status correctly kept (reset at default values for $V_{SREG} < V_{POR}$)
- Reset threshold correctly detected

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 7. Supply and supply monitoring

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.001	V_{SUV}	V_S undervoltage threshold	V_S increasing / decreasing	4.7		5.4	V
A.002	V_{hyst_UV}	V_S undervoltage hysteresis		0.04	0.1	0.2	V
A.003	V_{SOV}	V_S overvoltage threshold	V_S increasing	19.5		22.5	V
A.004			V_S decreasing	18.5		22.5	
A.005	V_{hyst_OV}	V_S overvoltage hysteresis		0.5	1	1.5	V

Table 7. Supply and supply monitoring (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.185	V_{SOV_DET}	V_S OverVoltage Detection threshold	V_S increasing	22.5	24	25.5	V
A.186			V_S decreasing	21	23	25	
A.187	$V_{hyst\_OV\_DET}$	V_S OverVoltage Detection hysteresis		0.5	1	1.5	V
A.006	V_{SREG_UV}	V_{SREG} undervoltage threshold	V_{SREG} increasing / decreasing	4.2		4.9	V
A.007	V_{hyst_UV}	V_{SREG} undervoltage hysteresis		0.04	0.1	0.2	V
A.008	V_{SREG_OV}	V_{SREG} overvoltage threshold	V_{SREG} increasing	19.5		22.5	V
A.009			V_{SREG} decreasing	18.5		22.5	
A.010	V_{hyst_OV}	V_{SREG} overvoltage hysteresis		0.5	1	1.5	V
A.011	t_{ovuv_filt}	V_S/V_{SREG} over/undervoltage filter time			64		µs
A.188	t_{FOV}	V_S OV Detection Filter Time	GENERATOR_MODE_EN = 1		64		µs
A.012	$I_{V(act)}$	Current consumption in Active mode	V_S = V_{SREG} = 12 V; TxD CAN = high; TxD LIN = high; V1 = ON; V2 = ON; HS/LS Driver OFF; CP = ON		11	15	mA
A.013	$I_{V(BAT)}$	Current consumption in VBAT_Standby mode(1)	V_S = 12 V; Both voltage regulators deactivated; HS/LS Driver OFF; No CAN communication; CAN automatic voltage biasing enabled	8	21	38	µA
A.014	$I_{V(BAT)CS}$	Current consumption in VBAT_Standby mode with cyclic sense enabled(1)	V_S = 12 V; Both voltage regulators deactivated; T = 50 ms, t_{ON} = 100 µs	40	100	143	µA
A.015	$I_{V(BAT)CW}$	Current consumption in VBAT_Standby mode with cyclic wake enabled(1)	V_S = 12 V; Both voltage regulators deactivated during standby phase	40	100	143	µA
A.016	$I_{V(V1stby)}$	Current consumption in V1_Standby mode(1)	V_S = 12 V; Voltage regulator V1 active; (I_{V1} = 0); HS/LS Driver OFF	16	56	86	µA
A.017		Current consumption in V1_Standby mode(1)(2)	V_S = 12 V; Voltage regulator V1 active; (I_{V1} = I_{CMP}); HS/LS Driver OFF			146	µA
A.019	I_{qCAN}	Quiescent current adder for CAN wake up activated	Guaranteed by design		0		µA

Table 7. Supply and supply monitoring (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.020	I_{qLIN}	Quiescent current adder for LIN wake up activated	Guaranteed by design		0		µA
A.021	I_{OUT15_DIR}	Quiescent current adder if OUT15 is configured for Direct Drive; value during output off	Guaranteed by design		0	5	µA
A.022	I_{timer}	Quiescent current adder if timer1 and/or timer 2 are active to provide interrupt on NINT upon timer expiration	Guaranteed by design		65	110	µA

1. Conditions for specified current consumption:
   V_{LIN} > (V_S-1.5 V)
   (V_{CAN_H} – V_{CAN_L}) < 0.4 V or (V_{CAN_H} – V_{CAN_L}) > 1.2 V
   V_{WU} < 1 V or V_{WU} > (V_{SREG} – 1.5 V)
2. Iq = Iq0 + 0.1% * I_{LOAD}; see also *Figure 6: Voltage regulator V1 characteristics (quiescent current and accuracy)*.

3.4.2 Oscillator

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 8. Oscillator

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.023	f_{CLK1}(1)	Oscillation frequency OSC1		1.66	2.0	2.34	MHz
A.024	f_{CLK2}(2)	Oscillation frequency OSC2		26.8	32.0	37.2	MHz

1. OSC1: charge pump, SPI, output drivers, watchdog.
2. OSC2: ADC, CAN.

3.4.3 Power-on reset (V_{SREG})

All outputs open; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 9. Power-on reset (VSREG)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.025	V_{POR_R}	V_{POR} threshold rising	V_{SREG} rising		3.45	4.5	V
A.026	V_{POR_F}	V_{POR} threshold falling	V_{SREG} falling(1) T_j = 25 ºC to 150 ºC	2.45		3.5	V
A.184			V_{SREG} falling(1) T_j = -40 ºC	2.1		3.5	

1. This threshold is valid if V_{SREG} had already reached $V_{POR\_R\ (max)}$ previously.

3.4.4 Voltage regulator V1

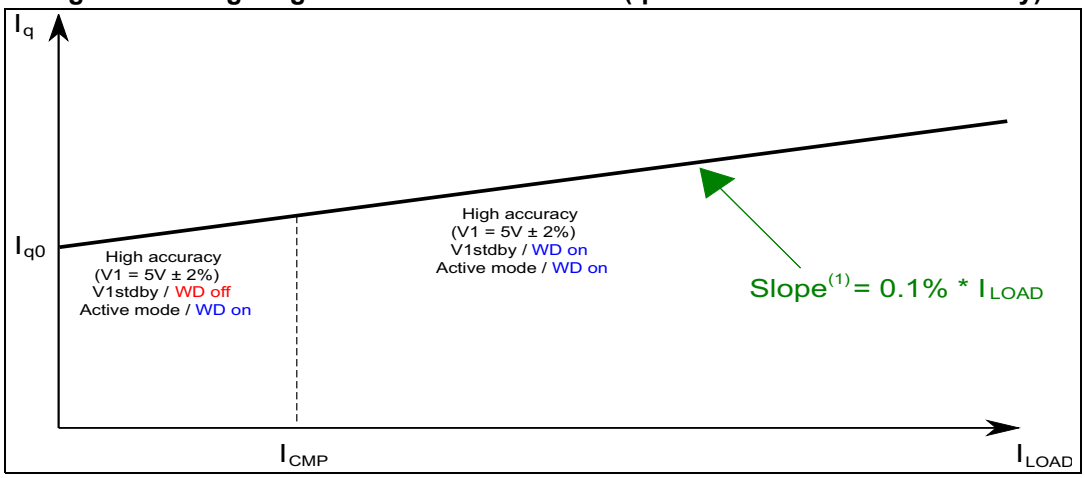
The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 4.5 V ≤ V_S ≤ 28 V; 4.5 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 10. Voltage regulator V1

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
C.001	V1	Output voltage	V_{SREG} = 13.5V		5.0		V
C.002	V_{SREG_absmin}	V_{SREG} absolute minimum value for controlling NRESET output	V_{SREG} rising/falling			2	V
C.004	$V1_{\_hi\_acc}$	Output voltage tolerance High accuracy mode	I_{LOAD} = 0 to 100 mA; V_{SREG} = 13.5 V	-2		2	%
C.005	$V1_{\_250mA}$	Output voltage tolerance (100 to 250 mA)	I_{LOAD} = 250 mA; V_{SREG} = 13.5 V	-3		3	%
C.006	V_{DP1}	Drop-out Voltage	I_{LOAD} = 50 mA; V_{SREG} = 5 V		0.2	0.4	V
C.007			I_{LOAD} = 100 mA; V_{SREG} = 5 V		0.3	0.5	V
C.008			I_{LOAD} = 150 mA; V_{SREG} = 5 V		0.45	0.6	V
C.009	I_{CC1}	Output current in Active mode	Max. continuous load current			250	mA
C.010	I_{CCmax1}	Short circuit output current	Current limitation	340	600	900	mA
C.011	C_{load1}	Load capacitor1	Ceramic (+/- 20%)	0.22[1]		10	µF
C.012	t_{TSD}	V1 deactivation time after thermal shut-down	Tested by scan		1		sec
C.013	I_{CMP_ris}	Current comp. rising thresh	Rising current	2	4.9	7	mA
C.014	I_{CMP_fal}	Current comp. falling threshold	Falling current	1.5	4	6	mA
C.015	I_{CMP_hys}	Current comp. Hysteresis			0.9		mA
C.019	$V1_{fail}$	V1 fail threshold	V1 forced		2		V
C.020	t_{V1fail}	V1 fail filter time	Tested by scan		2		µs
C.021	$t_{V1short}$	V1 short filter time	Tested by scan		4		ms
C.022	t_{V1FS}	V1 Fail-Safe Filter Time	Tested by scan		2		ms
C.023	t_{V1off}	V1 deactivation time after 8 consecutive WD failures	Tested by scan	150	200	250	ms

1. Nominal capacitor value required for stability of the regulator. Tested with 220 nF ceramic (+/- 20%). Capacitor must be located close to the regulator output pin. A 2.2 µF capacitor is recommended to minimize the DPI stress in the application.

Figure 6. Voltage regulator V1 characteristics (quiescent current and accuracy)



1. The 0.1% reported in the slope is Typical value.

3.4.5 Voltage regulator V2

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 4.5 V ≤ V_S ≤ 28 V; 4.5 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

In case the V2 regulator works as a classical voltage regulator (default case), the electrical specifications are reported in *Table 11*; in case V2 is configured to work as voltage tracker of V1, the electrical specifications are reported in *Table 12*.

Table 11. Voltage Regulator V2

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
C.024	V2	Output voltage	V_{SREG} = 13.5 V		5.0		V
C.025	V_{2_1mA}	Output voltage tolerance (0 to 1 mA)	I_{LOAD} = 1 mA; V_{SREG} = 13.5 V	-6.5		6.5	%
C.026	V_{2_25mA}	Output voltage tolerance (1 to 25 mA)	I_{LOAD} = 25 mA; V_{SREG} = 13.5 V	-3		3	%
C.027	V_{2_50mA}	Output voltage tolerance (25 to 50 mA)	I_{LOAD} = 50 mA; V_{SREG} = 13.5 V	-4		4	%
C.028	V_{2_100mA}	Output voltage tolerance (50 to 100 mA)	I_{LOAD} = 100 mA; V_{SREG} = 13.5 V	-4		4	%
C.029	V_{DP2}	Drop-out voltage	I_{LOAD} = 25 mA; V_{SREG} = 5.25 V		0.3	0.4	V
C.030			I_{LOAD} = 50 mA; V_{SREG} = 5.25 V		0.4	0.8	V
C.031			I_{LOAD} = 100 mA; V_{SREG} = 13.5 V		1	1.6	V
C.032	I_{CC2}	Output current in Active mode	Max. continuous load current			100	mA
C.033	I_{CCmax2}	Short circuit output current	Current limitation	100	150	250	mA

Table 11. Voltage Regulator V2 (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
C.034	C_{load}	Load capacitor	Ceramic (+/- 20%)	0.22(1)		10	µF
C.035	$V2_{fail}$	V2 fail threshold	V2 forced		2		V
C.036	t_{V2fail}	V2 fail filter time	Tested by scan		2		µs
C.037	$t_{V2short}$	V2 short filter time	Tested by scan		4		ms

1. Nominal capacitor value required for stability of the regulator. Tested with 220 nF ceramic (+/- 20%). Capacitor must be located close to the regulator output pin. A 2.2 µF capacitor is recommended to minimize the DPI stress in the application.

Table 12. Voltage Tracker V2

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
C.038	ΔVo	Output voltage tracking accuracy	I_{cc2_trk} = 100 µA to 50 mA, I_{cc1}=30mA, V_{sreg} = 6.5 V to 21 V	-15		15	mV
C.056			I_{cc2_trk} = 100 µA to 50 mA, I_{cc1}=30mA, V_{sreg} = 21 V to 28 V	-20		20	mV
C.039	V_{DP2}	Tracker Drop-out voltage	I_{cc2_trk} = 25 mA; VSREG = 5.25 V		0.3	0.4	V
C.040	I_{CC2_trk}	Tracker Output current in Active mode	Max. continuous load current			100	mA
C.041	I_{CCmax2_trk}	Tracker Output Current Limitation		100	150	250	mA
C.042	C_{load_trk}	Tracker Load capacitor	Ceramic (+/- 20%)	0.22 (1)		10	µF
C.043	$V2_{fail\_trk}$	V2 Tracker Short Circuit voltage to switch V2 off and set SPI bit (V2FAIL)			2	3	V
C.044	$t_{V2short\_trk}$	V2 tracker short filter time	Tested by scan		4		ms

1. Nominal capacitor value required for stability of the regulator. Tested with 220 nF ceramic (+/- 20%). Capacitor must be located close to the regulator output pin. A 2.2 µF capacitor is recommended to minimize the DPI stress in the application.

3.4.6 Reset output

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 4 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 13. Reset output

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
C.045	$V_{RT1falling}$	Reset threshold voltage1	V_{V1} decreasing	3.25	3.5	3.7	V
C.046	$V_{RT2falling}$	Reset threshold voltage2	V_{V1} decreasing	3.55	3.8	4	V
C.047	$V_{RT3falling}$	Reset threshold voltage3	V_{V1} decreasing	3.75	4.0	4.2	V
C.048	$V_{RT4falling}$	Reset threshold voltage4	V_{V1} decreasing	4.1	4.3	4.5	V
C.049	$V_{RTrising}$	Reset threshold voltage4	V_{V1} increasing	4.67	4.8	4.87	V

Table 13. Reset output (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
C.050	V_{RESET}	Reset Pin low output voltage	V1 > 1 V; I_{RESET} = 5 mA		0.2	0.4	V
C.051	R_{RESET}	Reset pull up int. resistor		10	20	30	kΩ
C.052	t_{RR}	Reset reaction time	I_{LOAD} = 1 mA, Tested by scan	6		40	µs
C.053	t_{UV1}	V1 undervoltage filter time	Tested by scan		16		µs
C.054	t_{V1R}	Reset pulse duration (V1 undervoltage and V1 power on reset)	Tested by scan	1.5	2.0	2.5	ms
C.055	t_{WDR}	Reset pulse duration (watchdog failure)	Tested by scan	3	4	5	ms

3.4.7 Watchdog timing

4.5 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 14. Watchdog timing

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.027	t_{LW}	Long open window	Tested by scan	160	200	240	ms
A.028	T_{EFW1}	Early Failure Window 1	Tested by scan			4.5	ms
A.029	T_{LFW1}	Late Failure Window 1	Tested by scan	20			ms
A.030	T_{SW1}	Safe Window 1	Tested by scan	7.5		12	ms
A.031	T_{EFW2}	Early Failure Window 2	Tested by scan			22.3	ms
A.032	T_{LFW2}	Late Failure Window 2	Tested by scan	100			ms
A.033	T_{SW2}	Safe Window 2	Tested by scan	37.5		60	ms
A.034	T_{EFW3}	Early Failure Window 3	Tested by scan			45	ms
A.035	T_{LFW3}	Late Failure Window 3	Tested by scan	200			ms
A.036	T_{SW3}	Safe Window 3	Tested by scan	75		120	ms
A.037	T_{EFW4}	Early Failure Window 4	Tested by scan			90	ms
A.038	T_{LFW4}	Late Failure Window 4	Tested by scan	400			ms
A.039	T_{SW4}	Safe Window 4	Tested by scan	150		240	ms

Figure 7. Watchdog timing

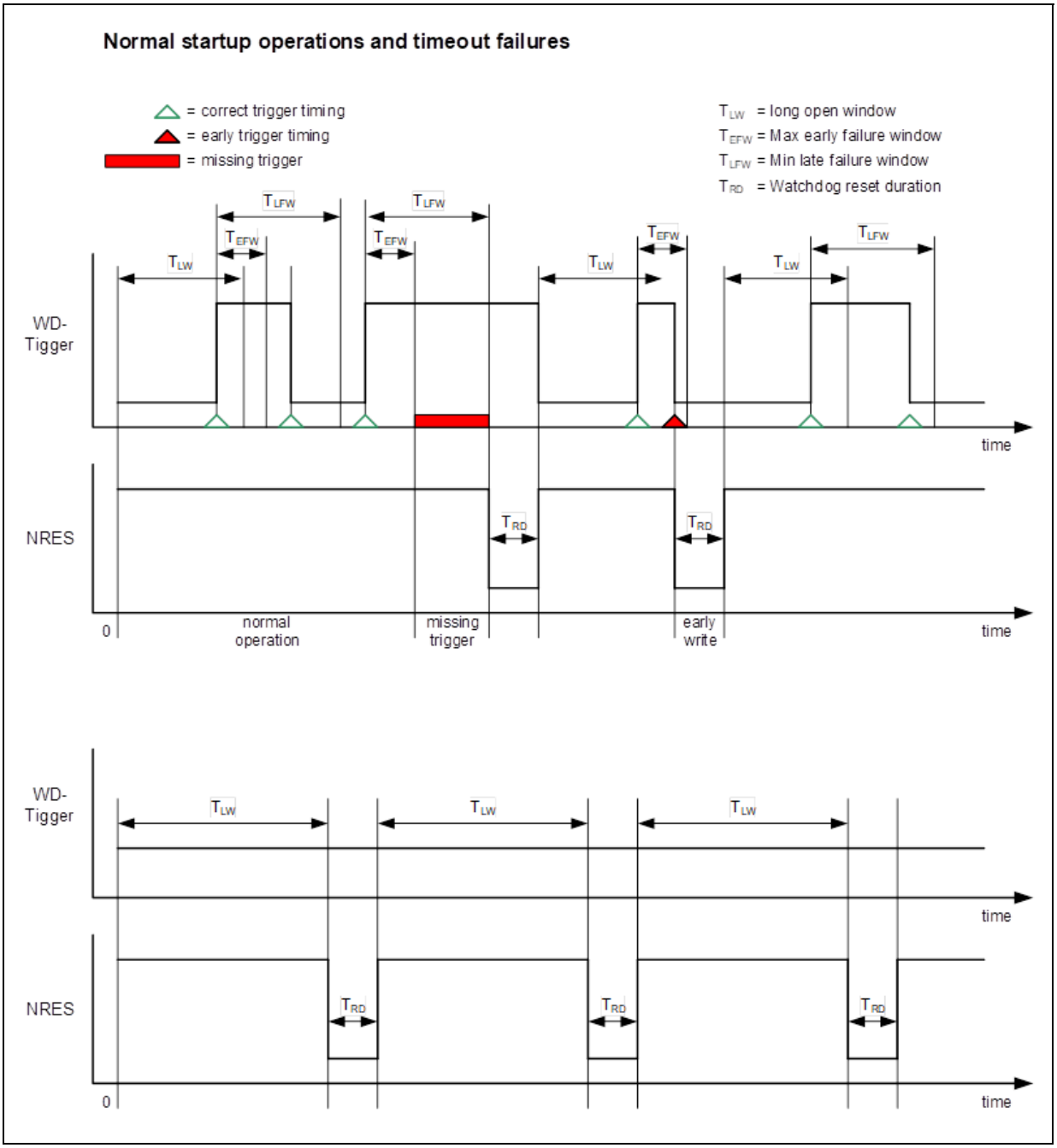
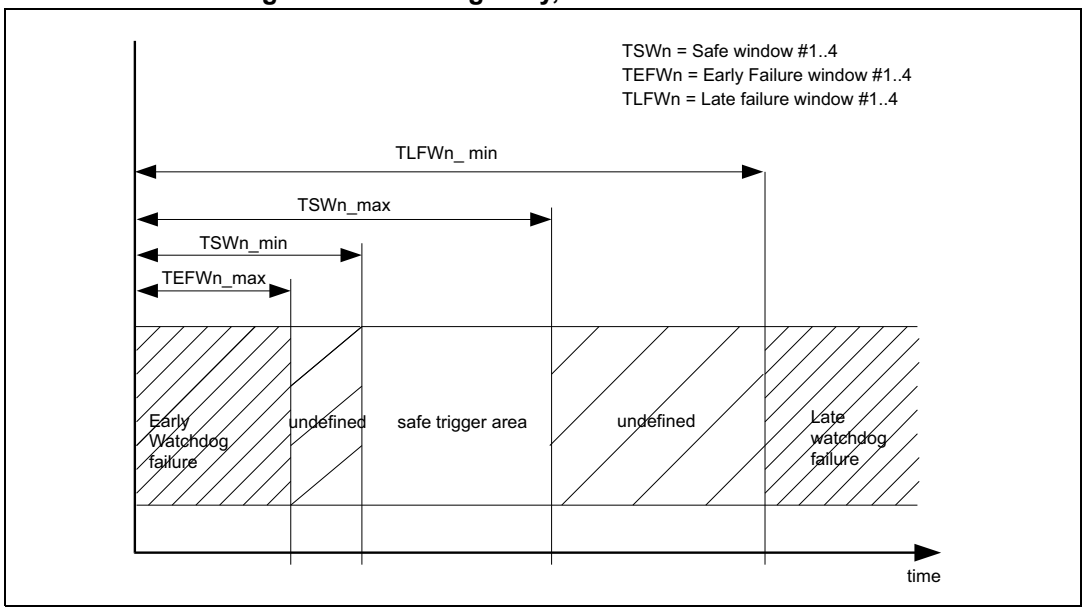


Figure 8. Watchdog early, late and safe windows



3.4.8 Current monitor output (CM)

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 15. Current monitor output (CM)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.040	V_{CM}	Functional voltage range		0		V_1-1V	V
A.041	I_{CMr}	Current monitor output ratio: ICM/IOUT1,6 and 7(low R_{ON})	0 V ≤ V_{CM} ≤ (V_1 - 1 V)		1/10000		
A.042		Current monitor output ratio: ICM/IOUT1,6 (high R_{ON})			1/5000		
A.043		Current monitor output ratio: ICM/IOUT8 (low R_{ON})			1/6500		
A.044		Current monitor output ratio: ICM/IOUT 2,3 and ICM/IOUT7,8 (high R_{ON})			1/2000		
A.045		Current monitor output ratio: ICM/IOUT9,10,13,14,15			1/1000		

Table 15. Current monitor output (CM) (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.046	$I_{CM\ acc\_2ol}$	Current monitor accuracy $acc I_{CMOUT1,6\ and\ 7}$ (low R_{ON})	0 V ≤ V_{CM} ≤ (V_1 - 1 V); I_{OUTmin}(1) = 2 * $I_{OLD1,6,7}$; $I_{OUT1,6max}$ = 7.4 A; $I_{OUT7max}$ = 1.4 A	-8%-2% FS(2)		8% + 2% FS(2)	
A.047		Current monitor accuracy $acc I_{CMOUT\ 8}$ (low on-resistance)	0 V ≤ V_{CM} ≤ (V_1 - 1 V); I_{OUTmin}(1)= 2 * I_{OLD8}; $I_{OUT8max}$ = 0.6 A				
A.048		Current monitor accuracy $acc I_{CMOUT\ 1,6}$ (high R_{ON})	0 V ≤ V_{CM} ≤ (V_1 - 1 V); I_{OUTmin}(1)= 2 * $I_{OLD1,6}$; $I_{OUT1,6max}$ = 2.9 A;				
A.049		Current monitor accuracy $acc I_{CMOUT2,\ 3,\ 9,\ 13,14,15}$ and $OUT_{7,8}$ (high R_{ON})	0 V ≤ V_{CM} ≤ (V_1 - 1 V); $I_{OUT.min}$(1) = 2*$I_{OLD2,3,9,13,14,15}$; $I_{OUT2,3max}$ = 0.4 A; $I_{OUT9,13,14max}$ = 0.3 A; I_{OUT15} = 0.2 A; $I_{OUT7,8\ max}$ = 0.3 A				
A.050		Current monitor accuracy $acc I_{CMOUT10}$	0 V ≤ V_{CM} ≤ (V_1 - 1 V); $I_{OUT.min}$(1) = 2 * I_{OLD10}; $I_{OUT10max}$ = 0.4 A				
A.051	t_{cmb}	Current monitor blanking time	Tested by scan		32		µs

1. IOUTmin = 2 * IOLDmax for OUT9, 10, 13, 14 and 15 in low current mode. IOUTmin = 2 * IOLDtyp for the other cases.
2. FS (full scale) = IOUTmax * ICMr.

3.4.9 Charge pump

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 16. Charge pump electrical characteristics

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.052	V_{CP}	Charge pump output voltage	V_S = 6 V, I_{CP} = -15 mA	V_S+6	V_S+7		V
A.053			V_S ≥ 10 V, I_{CP} = -15 mA	V_S+11	V_S+12	V_S+13.5	V
A.054	I_{CP}	Charge pump output current(1)	V_{CP} = V_S + 10 V; V_S = 13.5 V; C_1 = C_2 = C_{CP} = 100 nF	22.5			mA
A.055	I_{CPlim}	Charge pump output current limitation(2)	V_{CP} = V_S; V_S = 13.5 V; C_1 = C_2 = C_{CP} = 100 nF			70	mA
A.056	V_{CP_low}	Charge pump low threshold voltage		V_S+4.5	V_S+5	V_S+5.5	V

Table 16. Charge pump electrical characteristics (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.057	T_{CP}	Charge pump low filter time	Tested by scan		64		µs
A.058	f_{CP}	Charge Pump frequency	Tested by scan		400		kHz

1. I_{CP} is the minimum current the device can provide to an external circuit without V_{CP} going below V_S + 10 V.
2. I_{CPlim} is the maximum current, which flows out of the device in case of a short to V_S.

3.4.10 Outputs OUT1 - OUT15, ECV, ECDR

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V, all outputs open; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 17. Outputs OUT1 - OUT15, ECV and ECDR

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.001	$r_{ON\ OUT1,6}$ (low rdson)	On-resistance to supply or GND	V_S = 13.5 V; T_j = 25°C; $I_{OUT1,6}$ = ±3 A		150		mΩ
D.002			V_S = 13.5 V; T_j = 130°C $I_{OUT1,6}$ = ±1.5 A and ±3 A(1)			300	mΩ
D.003	$r_{ON\ OUT1,6}$ (high rdson)	On-resistance to supply or GND	V_S = 13.5 V; T_j = 25°C; $I_{OUT1,6}$ = ±1.5 A		300		mΩ
D.004			V_S = 13.5 V; T_j = 130°C $I_{OUT1,6}$ = ±1.5 A			600	mΩ
D.005	$r_{ON\ OUT2,3}$	On-resistance to supply or GND	V_S = 13.5 V; T_j = 25 °C; $I_{OUT2,3}$ = ±0.25 A		2000		mΩ
D.006			V_S = 13.5 V; T_j = 130 °C; $I_{OUT2,3}$ = ±0.25 A			4000	mΩ
D.007	$r_{ON\ OUT7}$	On-resistance to supply in low resistance mode	V_S = 13.5 V; T_j = 25 °C; I_{OUT7} = -0.8 A		500		mΩ
D.008			V_S = 13.5 V; T_j = 130 °C; I_{OUT7} = -0.8 A			1000	mΩ
D.009		On-resistance to supply in high resistance mode	V_S = 13.5 V; T_j = 25°C; I_{OUT7} = -0.2 A		1600		mΩ
D.010			V_S = 13.5 V; T_j = 130 °C; I_{OUT7} = -0.2 A			3200	mΩ
D.011	$r_{ON\ OUT8}$	On-resistance to supply in low resistance mode	V_S = 13.5 V; T_j = 25 °C; I_{OUT8} = -0.4 A		800		mΩ
D.012			V_S = 13.5 V; T_j = 130 °C; I_{OUT8} = -0.4 A			1600	mΩ
D.013		On-resistance to supply in high resistance mode	V_S = 13.5 V; T_j = 25 °C; I_{OUT8} = -0.2 A		1600		mΩ
D.014			V_S = 13.5 V; T_j = 130 °C; I_{OUT8} = -0.2 A			3200	mΩ

Table 17. Outputs OUT1 - OUT15, ECV and ECDR (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.015	r_{ON} OUT9,10,13,14	On-resistance to supply	V_S = 13.5 V; T_j = 25 °C; $I_{OUT9,10,13,14}$ = -75 mA		2000		mΩ
D.016			V_S = 13.5 V; T_j = 130 °C; $I_{OUT9,10,13,14}$ = -75 mA			4000	mΩ
D.017	$r_{ON\ OUT15}$	On-resistance to supply	V_S = 13.5 V; T_j = 25 °C; I_{OUT15} = -75 mA		5		Ω
D.018			V_S = 13.5 V; T_j = 130 °C; I_{OUT15} = -75 mA			10	Ω
D.019	$r_{ON\ ECV}$	On-resistance to GND	V_S = 13.5 V; T_j = 25 °C; $I_{OUTECV,ECFD}$ = +0.4 A		1600	2200	mΩ
D.020			V_S = 13.5 V; T_j = 130 °C; $I_{OUTECV,ECFD}$ = +0.4 A		2500	3400	mΩ
D.021	I_{QLH}	Switched-off output current high-side drivers of OUT7- 8-9-10-13-14-15	V_{OUT} = 0 V; standby mode	-5			µA
D.022			V_{OUT} = 0 V; active mode	-10			µA
D.023	I_{QLH}	Switched-off output current high-side drivers of OUT1-2-3-6	V_{OUT} = 0 V; standby mode	-5			µA
D.024			V_{OUT} = 0 V; active mode	-100			µA
D.025	I_{QLL}	Switched-off output current low-side drivers of OUT1-2-3-6	V_{OUT} = V_S; standby mode			165	µA
D.026			V_{OUT} = V_S - 0.5 V; active mode	-100			µA
D.027		Switched-off output current low-side driver of ECV	V_{OUT} = V_S - 2.5 V with ECDR = V_S; standby mode	-15		15	µA
D.028			V_{OUT} = V_S - 2.5 V with ECDR = V_S; active mode	-10			µA

1. Guaranteed by design.

3.4.11 Power outputs switching times

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 18. Power outputs switching times

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.029	$t_{d\ ON\ H}$	Output delay time high-side driver on ($OUT_{1,2,3,6}$)	V_S = 13.5 V; V_1 = 5 V; corresponding low-side driver is not active [1][2][3](from CSN 50% to OUT 50% see *Figure 16: SPI CSN - output timing*)	15	40	80	µs
D.030		Output delay time high-side driver on ($OUT_{7,8}$)		20	40	90	µs

Table 18. Power outputs switching times (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.031	$t_{d\ OFF\ H}$	Output delay time high-side driver off ($OUT_{1,6}$)	V_S = 13.5 V; V_1 = 5 V (1)(3) (from CSN 50% to OUT 50%) see *Figure 16: SPI CSN - output timing*	20	150	300	µs
D.032		Output delay time high-side driver off ($OUT_{2,3,7,8}$)		10	70	130	µs
D.033	$t_{d\ ON\ H}$	Output delay time high-side driver on (OUT9, OUT10, OUT13, OUT14, OUT15)	V_S/V_{SREG} = 13.5 V; V_1 = 5 V; (from CSN 80% to OUT 80%)			30	µs
D.034	$t_{d\ OFF\ H}$	Output switch off delay time high- side driver on (OUT9, OUT10, OUT13, OUT14, OUT15)	V_S/V_{SREG} = 13.5 V; V_1 = 5 V; (from CSN 80% to OUT 20%)			35	µs
D.035	$t_{d\ ON\ L}$	Output delay time low-side driver ($OUT_{1-2-3-6}$, ECV) on	V_S = 13.5 V; V_1 = 5 V; corresponding high-side driver is not active(1)(3) (from CSN 50% to OUT 50%) see *Figure 16: SPI CSN - output timing*	15	30	70	µs
D.036	$t_{d\ OFF\ L}$	Output delay time low-side driver ($OUT_{1-2-3-6}$) off	V_S = 13.5 V; V_1 = 5 V (1)(3) (from CSN 50% to OUT 50%) see *Figure 16: SPI CSN - output timing*	40	150	300	µs
D.037		Output delay time low-side driver (ECV) off	V_S = 13.5 V; V_1 = 5 V (1)(2)(3) (from CSN 50% to OUT 50%) see *Figure 16: SPI CSN - output timing*	15	45	110	µs
D.038	$t_{d\ HL}$	Cross current protection time ($OUT_{1-2-3-6}$)	$t_{cc\ ONLS\_OFFHS} - t_{d\ OFF\ L}$(4)	50	200	480	µs
D.039	$t_{d\ LH}$		$t_{cc\ ONHS\_OFFLS} - t_{d\ OFF\ L}$ (4)				
D.040	dV_{OUT}/dt	Slew rate of OUT_1-OUT_8, ECV	V_S = 13.5 V; V_1 = 5 V(1)(2)(3)	0.1	0.2	0.6	V/µs
D.041	dVmax/dt	Maximum external applied slew rate on OUT1-2-3-6 without switching on the LS and HS (only in Active mode)	Guaranteed by design	20			V/µs
D.042	dV_{OUT}/dt	Slew rate of OUT9, OUT10, OUT13, OUT14-OUT15	V_S/V_{SREG} = 13.5 V; V_1 = 5 V (1)(3)	1	2	3	V/µs
D.043	$f_{PWMx}(00)$	PWM switching frequency	V_S/V_{SREG} = 13.5 V; V_1 = 5 V Tested by scan		100		Hz
D.044	$f_{PWMx}(01)$	PWM switching frequency	V_S/V_{SREG} = 13.5 V; V_1 = 5 V Tested by scan		200		Hz
D.045	$f_{PWMx}(10)$	PWM switching frequency	V_S/V_{SREG} = 13.5 V; V_1 = 5 V Tested by scan		330		Hz
D.046	$f_{PWMx}(11)$	PWM switching frequency	V_S/V_{SREG} = 13.5 V; V_1 = 5 V Tested by scan		500		Hz

1. R_{LOAD} = 16 Ω at $OUT_{1,6}$ in high on-resistance mode and $OUT_{7,8}$ in low on-resistance mode.

2. R_{LOAD} = 4 Ω at $OUT_{4,5\ 1,6}$ in low on-resistance mode.
3. R_{LOAD} = 128 Ω at $OUT_{2,3,4,9,10,13,14,\ 15}$, ECV and $OUT_{7,8}$ in high on-resistance mode.
4. t_{CC} is the switch-on delay time if complement in half bridge has to switch off.

3.4.12 Current Monitoring

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 19. Current monitoring

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.047	$\|I_{SC\_OUT2}\|$, $\|I_{SC\_OUT3}\|$	Short-circuit threshold HS & LS	V_S = 13.5 V, V1 = 5 V, sink Full V_S ranges guaranteed by design	1.05		1.8	A
D.048	$\|I_{SC\_OUT1}\|$, $\|I_{SC\_OUT6}\|$	Short-circuit threshold HS & LS in low on resistance mode	V_S = 13.5 V, V1 = 5 V, sink Full V_S ranges guaranteed by design	11		17	A
D.049		Short-circuit threshold HS & LS in high on resistance mode		5.5		9	A
D.050	$\|I_{OC2}\|$, $\|I_{OC3}\|$	Over-current threshold HS & LS	V_S = 13.5 V, V1 = 5 V, sink Full V_S ranges guaranteed by design	0.5		1	A
D.051	$\|I_{OC1}\|$, $\|I_{OC6}\|$	Over- current threshold HS & LS in low on resistance mode	V_S = 13.5 V, V1 = 5 V, sink and source; Tj = -40 °C to 130 °C	7.5		11	A
D.052		Over - current threshold HS & LS in high on resistance mode	V_S = 13.5 V, V1 = 5 V, sink Full V_S ranges guaranteed by design	3		5	A

Table 19. Current monitoring (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.053	$\|I_{OC7}\|$	Overcurrent threshold HS in low on- resistance mode	V_S/V_{SREG} = 13.5 V; V_1 = 5 V; source	1.5		2.5	A
D.054		Overcurrent threshold HS in high on-resistance mode		0.35		0.65	A
D.055	$\|I_{OC8}\|$	Overcurrent threshold HS in low on- resistance mode		0.7		1.3	A
D.056		Overcurrent threshold HS in high on-resistance mode		0.35		0.65	A
D.057	$\|I_{OC9}\|$, $\|I_{OC13}\|$, $\|I_{OC14}\|$	Overcurrent threshold HS in high current mode		0.35		0.7	A
D.058		Overcurrent threshold to HS in low current mode		0.15		0.3	A
D.059	$\|I_{OC10}\|$	Overcurrent threshold HS in high current mode		0.5		1	A
D.060		Overcurrent threshold HS in low current mode		0.25		0.5	A
D.061	$\|I_{OC15}\|$	Overcurrent threshold HS in high current mode		0.25		0.5	A
D.062		Overcurrent threshold HS in low current mode		0.15		0.3	A
D.063	$\|I_{OCECV}\|$	output current threshold LS	V_S = 13.5 V; V_1= 5 V; sink	0.5		1.0	A
D.064	$\|I_{CCM8}\|$ $\|I_{CCM9}\|$	Constant Current value for OUT8 and OUT9	V_S = 13.5 V; V_{OUTx} > 3.0 V ; OUTx_CCM_EN = 1 (x= 8, 9)	100	175	250	mA
D.093	$\|I_{CCM7}\|$	Constant Current value for OUT7	V_S = 13.5 V; V_{OUT7} > 3.0V ; OUT7_CCM_EN = 1 (1)	80	175	250	mA
D.065	$t_{CCMtimeout}$	Constant Current Mode expiration time	OUTx_CCM_EN = 1 (x= 7, 8, 9) (2) (3)		10		ms
D.066	t_{FSC}	Filter time of short-circuit signal in all drivers	(2)	1	2	3	µs
D.067	t_{BLK}	Blanking time of over-current signal in Half Bridges and in High Sides	Guaranteed by design		40		µs
D.068	t_{OCR00}	Over Current Filter Time for Half Bridges and High Side Drivers 7, 8 and 15	OUTxx_OCR_TON = 00 (2)(3)		88		µs
D.069	t_{OCR01}		OUTxx_OCR_TON = 01 (2)(3)		80		µs
D.070	t_{OCR10}		OUTxx_OCR_TON = 10 (2)(3)		72		µs
D.071	t_{OCR11}		OUTxx_OCR_TON = 11 (2)(3)		64		µs
D.072	f_{rec00}	Recovery frequency for OC configurable in CR8	OUTxx_OCR_FREQ = 00 (2)(3)		1.7		kHz
D.073	f_{rec01}		OUTxx_OCR_FREQ = 01 (2)(3)		2.2		kHz
D.074	f_{rec10}		OUTxx_OCR_FREQ = 10 (2)(3)		3		kHz
D.075	f_{rec11}		OUTxx_OCR_FREQ = 11 (2)(3)		4.4		kHz

Table 19. Current monitoring (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
D.076	t_{AR_HB}	Auto recovery time limit for Half Bridges (OUT1, OUT2, OUT3, OUT6)	Tested by scan		100		ms
D.077	t_{AR_HS}	Auto recovery time limit for High Sides (OUT7, OUT8, OUT15)	Tested by scan		120		ms
D.078	$\|I_{OLD2}\|$, $\|I_{OLD3}\|$	Under-current threshold HS & LS	V_S = 13.5 V, V1 = 5 V, sink and source	6	20	30	mA
D.079	$\|I_{OLD1}\|$, $\|I_{OLD6}\|$	Under-current threshold HS & LS in low on-resistance mode	V_S = 13.5 V, V1 = 5 V, sink and source	40	150	300	mA
D.080		Under-current threshold HS & LS in high on-resistance mode		6	30	90	mA
D.081	$\|I_{OLD7}\|$	Under-current threshold HS in low on-resistance mode	V_S/V_{SREG} = 13.5 V; V_1 = 5 V; source	15	40	60	mA
D.082		Under-current threshold HS in high on-resistance mode		5	10	15	mA
D.083	$\|I_{OLD8}\|$	Under-current threshold HS in low on-resistance mode		10	30	45	mA
D.084		Under-current threshold HS in high on-resistance mode		5	10	15	mA
D.085	$\|I_{OLD9}\|$, $\|I_{OLD13}\|$, $\|I_{OLD14}\|$	Under-current threshold HS in high current mode		6		12	mA
D.086		Under-current threshold HS in low current mode		0.25		4	mA
D.087	$\|I_{OLD10}\|$	Under -current threshold HS in high current mode		10		30	mA
D.088		Under -current threshold HS in low current mode		0.8		4	mA
D.089	$\|I_{OLD15}\|$	Under -current threshold HS in high current mode		6		12	mA
D.090		Under -current threshold HS in low current mode		0.5		4	mA
D.091	$\|I_{OLDECV}\|$	Under-current threshold LS	V_S = 13.5 V; V_1 = 5 V; sink	6	20	30	mA
D.092	t_{OL_out}	Filter time of open-load signal	Duration of open-load condition to set the status bit (2)	150	200	250	µs

1. OUT7 in high on-resistance mode.
2. Tested by scan.
3. Where xx = HB, 7, 8, 15.

3.4.13 Heater

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 20. Heater

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.059	$I_{GHheater}$	Average charge-current (charge stage)	T_j = 25 °C		0.3		A
A.060	$R_{GLheater}$	On-resistance (discharge-stage)	V_{SLx} = 0 V; I_{GHx} = 50 mA; T_j = 25 °C	4	8	10	Ω
A.061			V_{SLx} = 0 V; I_{GHx} = 50 mA; T_j = 130 °C		11	14	Ω
A.062	$V_{GHheater}$	Gate-on voltage	V_S = SH= 6 V; I_{CP} = 15 mA	$V_{SHheater}$ + 6			V
A.063			V_S = SH = 12 V; I_{CP} = 15 mA	$V_{SHheater}$ + 8	$V_{SHeater}$ + 10	$V_{SHeater}$ + 11.5	V
A.064	$R_{GSHeater}$	Passive gate-clamp resistance			15		kΩ
A.065	$T_{G(HL)xHL}$	Propagation delay time high to low (switch mode)	V_S = 13.5 V; V_{SHx} = 0; R_G = 0 Ω; C_G = 2.7 nF		1.5		µs
A.066	$T_{G(HL)xLH}$	Propagation delay time low to high (switch mode)	V_S = 13.5 V; V_{SLx} = 0; R_G = 0 Ω; C_G = 2.7 nF		1.5		µs
A.067	$t0_{GHheaterr}$	Rise time (switch mode)	V_S = 13.5 V; $V_{Sheater}$ = 0; R_G = 0 Ω; C_G = 2.7 nF		45		ns
A.068	$t0_{GHheaterf}$	Fall time (switch mode)	V_S = 13.5 V; $V_{Sheater}$ = 0; R_G = 0 Ω; C_G = 2.7 nF		85		ns

3.4.14 H-bridge driver

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40°C to 150 °C, unless otherwise specified.

Table 21. H-bridge driver

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
Drivers for external high-side PowerMOS							
A.069	$I_{GHx(Ch)}$	Average charge current (charge stage)	T_j = 25 °C		0.3		A

Table 21. H-bridge driver (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.070	R_{GHx}	On-resistance (discharge- stage)	V_{SHx} = 0 V; I_{GHx} = 50 mA; T_j = 25 °C	4	10	14	Ω
A.071			V_{SHx} = 0 V; I_{GHx} = 50 mA; T_j = 130 °C		14	20	Ω
A.072	V_{GHHx}	Gate-on voltage	V_S = SH = 6 V; I_{CP} = 15 mA	V_{SHx} + 6			V
A.073			V_S = SH = 12 V; I_{CP} = 15 mA	V_{SHx} + 8	V_{SHx} + 10	V_{SHx} + 11.5	V
A.074	R_{GSHx}	Passive gate-clamp resistance	V_{GHx} = 0.5 V		15		kΩ
Drivers for external low-side Power-MOS							
A.075	$I_{GLx(Ch)}$	Average charge-current (charge stage)	T_j = 25 °C		0.3		A
A.076	R_{GLx}	On-resistance (discharge- stage)	V_{SLx} = 0 V; I_{GHx} = 50 mA; T_j = 25 °C	4	10	14	Ω
A.077			V_{SLx} = 0 V; I_{GHx} = 50 mA; T_j = 130 °C		14	20	Ω
A.078	V_{GHLx}	Gate-on voltage	V_S = 6 V; I_{CP} = 15 mA	V_{SLx} + 6			V
A.079			V_S = 12 V; I_{CP} = 15 mA	V_{SLx} + 8	V_{SLx} + 10	V_{SLx} + 11.5	V
A.080	R_{GSLx}	Passive gate-clamp resistance			15		kΩ

3.4.15 Gate drivers for the external Power-MOS switching times

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 22. Gate drivers for the external Power-MOS switching times

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.081	$T_{G(HL)xHL}$	Propagation delay time high to low (switch mode)(1)	V_S = 13.5 V; V_{SHx} = 0; R_G = 0 Ω; C_G = 2.7 nF		1.5		µs
A.082	$T_{G(HL)xLH}$	Propagation delay time low to high (switch mode)(1)	V_S = 13.5 V; V_{SLx} = 0; R_G = 0 Ω; C_G = 2.7 nF		1.5		µs
A.083	$I_{GHxrmax}$	Maximum source current (current mode)	V_S = 13.5 V; V_{SHx} = 0; V_{GHx} = 1 V; SLEW<4:0> = 1 F_H		32		mA
A.084	$I_{GHxfmax}$	Maximum sink current (current mode)	V_S = 13.5 V, V_{SHx} = 0; V_{GHx} = 2 V; SLEW<4:0> = 1 F_H		32		mA

Table 22. Gate drivers for the external Power-MOS switching times (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.085	dI_{IGHxr}	Source current accuracy	V_S = 13.5 V; V_{SHx} = 0; V_{GHx} = 1 V	See *Figure 10: IGHxr ranges*			
A.086	dI_{IGHxf}	Sink current accuracy	V_S = 13.5 V; V_{SHx} = 0; V_{GHx} = 2 V	See *Figure 11: IGHxf ranges*			
A.087	$V_{DSHxrSW}$	Switching voltage (V_S-V_{SH}) between current mode and switch mode (rising)	V_S = 13.5 V		2.8		V
A.088	$V_{DSHxfSW}$	Switching voltage (V_S-V_{SH}) between switch mode and current mode (falling)	V_S = 13.5 V		2.8		V
A.089	$t0_{GHxr}$	Rise time (switch mode)	V_S = 13.5 V; V_{SHx} = 0; R_G = 0 Ω; C_G = 2.7 nF		45		ns
A.090	$t0_{GHxf}$	Fall time (switch mode)	V_S = 13.5 V; V_{SHx} = 0; R_G = 0 Ω; C_G = 2.7 nF		85		ns
A.091	$t0_{GLxr}$	Rise time	V_S = 13.5 V; V_{SLx} = 0; R_G = 0 Ω; C_G = 2.7 nF		45		ns
A.092	$t0_{GLxf}$	Fall time	V_S = 13.5 V; V_{SLx} = 0; R_G = 0 Ω; C_G = 2.7 nF		85		ns
A.093	$tccp_{0000}$	Programmable cross-current protection time			250		ns
A.094	$tccp_{0001}$	Programmable cross-current protection time	Tested by scan		500		ns
A.095	$tccp_{0010}$	Programmable cross-current protection time	Tested by scan		750		ns
A.096	$tccp_{0011}$	Programmable cross-current protection time	Tested by scan		1000		ns
A.097	$tccp_{0100}$	Programmable cross-current protection time	Tested by scan		1250		ns
A.098	$tccp_{0101}$	Programmable cross-current protection time	Tested by scan		1500		ns
A.099	$tccp_{0110}$	Programmable cross-current protection time	Tested by scan		1750		ns
A.100	$tccp_{0111}$	Programmable cross-current protection time	Tested by scan		2000		ns
A.101	$tccp_{1000}$	Programmable cross-current protection time	Tested by scan		2250		ns
A.102	$tccp_{1001}$	Programmable cross-current protection time	Tested by scan		2500		ns
A.103	$tccp_{1010}$	Programmable cross-current protection time	Tested by scan		2750		ns
A.104	$tccp_{1011}$	Programmable cross-current protection time	Tested by scan		3000		ns

Table 22. Gate drivers for the external Power-MOS switching times (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.105	$t_{CCP1100}$	Programmable cross-current protection time	Tested by scan		3250		ns
A.106	$t_{CCP1101}$	Programmable cross-current protection time	Tested by scan		3500		ns
A.107	$t_{CCP1110}$	Programmable cross-current protection time	Tested by scan		3750		ns
A.108	$t_{CCP1111}$	Programmable cross-current protection time	Tested by scan		4000		ns
A.109	f_{PWMH}	PWMH switching frequency(1)	V_S = 13.5 V; V_{SLx} = 0; R_G = 0 Ω; C_G = 2.7 nF; PWMH-Duty-Cycle = 50%, Tested by scan			50	kHz

1. Without cross-current protection time t_{CCP}.

Figure 9. H-driver delay times

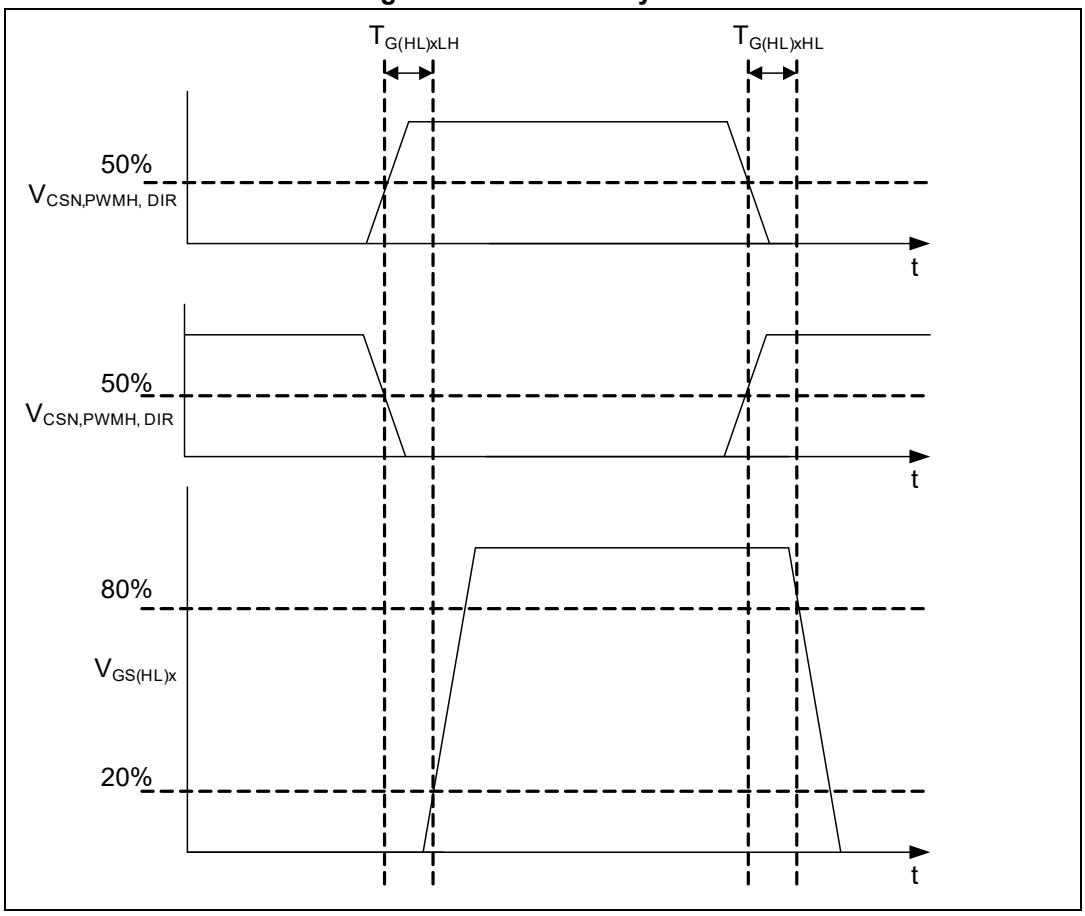


Figure 10. IGHxr ranges

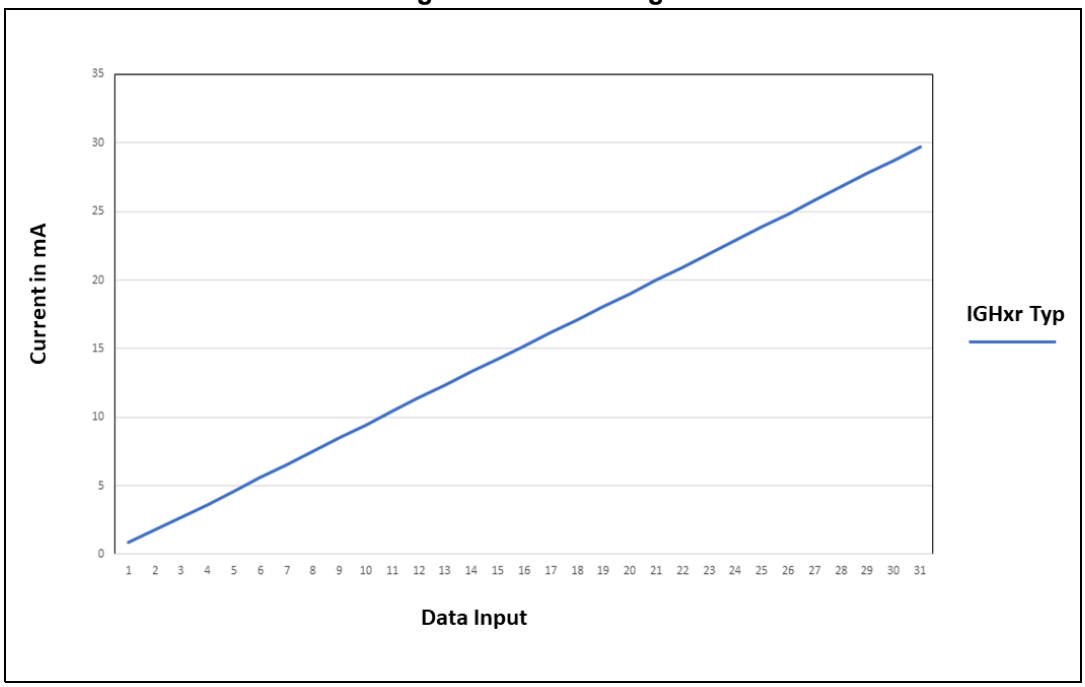
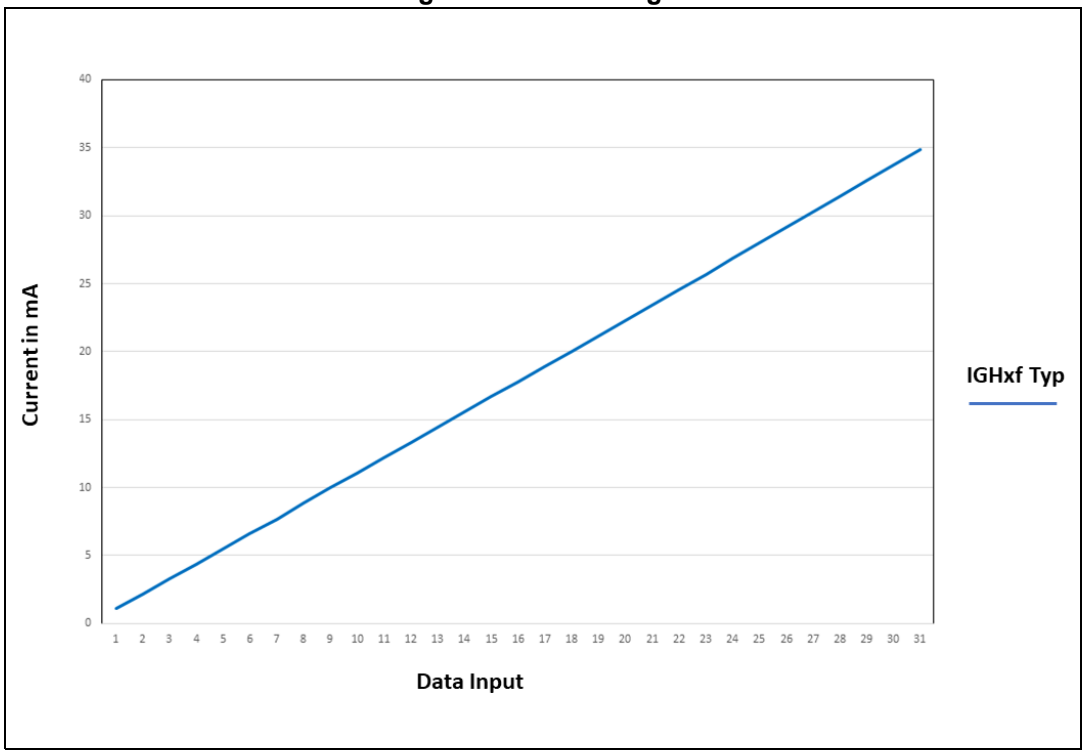


Figure 11. IGHxf ranges



3.4.16 Drain source monitoring external H-bridges

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40°C to 150 °C, unless otherwise specified.

Table 23. Drain source monitoring external H-bridge

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.110	V_{SCd1_HB}	Drain-source threshold voltage		0.375	0,5	0.625	V
A.111	V_{SCd2_HB}	Drain-source threshold voltage		0.6	0,75	0.9	V
A.112	V_{SCd3_HB}	Drain-source threshold voltage		0,85	1	1,15	V
A.113	V_{SCd4_HB}	Drain-source threshold voltage		1,06	1,25	1,43	V
A.114	V_{SCd5_HB}	Drain-source threshold voltage		1,27	1,5	1,73	V
A.115	V_{SCd6_HB}	Drain-source threshold voltage		1,49	1,75	2,01	V
A.116	V_{SCd7_HB}	Drain-source threshold voltage		1,7	2	2,3	V
A.117	t_{SCd_HB}	Drain-source monitor filter time	Tested by scan		6		µs
A.118	t_{scs_HB}	Drain-source comparator settling time	V_S = 13.5 V; V_{SH} = jump from GND to V_S			5	µs

3.4.17 Drain source monitoring external heater MOSFET

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 24. Drain source monitoring external heater MOSFET

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.119	V_{SCd1_HE}	Drain-source threshold voltage		160	200	250	mV
A.120	V_{SCd2_HE}	Drain-source threshold voltage		200	250	305	mV
A.121	V_{SCd3_HE}	Drain-source threshold voltage		240	300	360	mV
A.122	V_{SCd4_HE}	Drain-source threshold voltage		280	350	420	mV
A.123	V_{SCd5_HE}	Drain-source threshold voltage		320	400	480	mV
A.124	V_{SCd6_HE}	Drain-source threshold voltage		360	450	540	mV
A.125	V_{SCd7_HE}	Drain-source threshold voltage		400	500	600	mV
A.126	V_{SCd8_HE}	Drain-source threshold voltage		440	550	660	mV
A.127	t_{SCd_HE}	Drain-source monitor filter time	Tested by scan		6		µs
A.128	t_{scs_HE}	Drain-source comparator settling time	V_S = 13.5 V; V_{SH} = jump from GND to V_S			5	µs
A.129	t_{scbl_HE}	Drain-source monitoring blanking time	Tested by scan		8		µs

3.4.18 Open-load monitoring external H-bridges

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 25. Open-load monitoring external H-bridge

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.130	V_{ODSL}	Low-side drain-source monitor low off-threshold voltage	V_{SLx} = 0 V; V_S = 13.5 V		0.15 V_S		V
A.131	V_{ODSH}	Low-side drain-source monitor high off-threshold voltage	V_{SLx} = 0 V; V_S = 13.5 V		0.85 V_S		V
A.132	V_{OLSHx}	Output voltage of selected SHx in open-load test mode	V_{SLx} = 0 V; V_S = 13.5 V		0.5 V_S		V
A.133	R_{pdOL}	Pull-down resistance of the non- selected SHx pin in open-load mode	V_{SLx} = 0 V; V_S = 13.5 V; V_{SHX} = 4.5 V		20		kΩ
A.134	t_{OL_HB}	Open-load filter time	Tested by scan		2		ms

3.4.19 Open-load monitoring external heater MOSFET

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 26. Open-load monitoring external heater MOSFET

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.135	$V_{OLheater}$	Open-load -threshold voltage	V_{SLx} = 0 V; V_S = 13.5 V		2		V
A.136	$I_{OLheater}$	Pull-up current source open-load diagnosis activated	V_{SLx} = 0 V; V_S = 13.5 V; $V_{SHheater}$ = 4.5 V		1		mA
A.137	t_{OL_HE}	Open-load filter time	Tested by scan		2		ms

3.4.20 Electro-chrome mirror driver

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 28 V; 6 V ≤ V_{SREG} ≤ 28 V; T_j = -40°C to 150°C, unless otherwise specified.

Table 27. Electro-chrome mirror driver

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.138	$V_{CTRLmax}$	Maximum EC-control voltage	ECV_HV (Config Reg) = 1(1)	1.4		1.6	V
A.139			ECV_HV (Config Reg) = 0(1)	1.12		1.28	V
A.140	DNL_{ECV}	Differential Non Linearity		-2		2	LSB(2)
A.141	$\|dV_{ECV}\|$	Voltage deviation between target and ECV	$dV_{ECV} = V_{target}$(3) $- V_{ECV}$; $\|I_{ECDR}\| < 1$ µA	-5% - 1LSB(2)		+5% + 1LSB(2)	mV
A.142	dV_{ECVnr}	Difference voltage between target and ECV sets flag if V_{ECV} is below it	$dV_{ECV} = V_{target}$(3) $- V_{ECV}$; toggle bitx = 1; status reg. x		120		mV
A.143	dV_{ECVhi}	Difference voltage between target and ECV sets flag if V_{ECV} is above it	$dV_{ECV} = V_{target}$(3) $- V_{ECV}$; toggle bitx = 1; status reg. x		-135		mV
A.144	t_{FECVNR}	ECV_{NR} filter time	Tested by scan		32		µs
A.145	t_{FECVHI}	ECV_{HI} filter time	Tested by scan		32		µs
A.146	$V_{ECDRminHIGH}$	Output voltage range	I_{ECDR} = -10 µA	V1 -0.3 V		V1	V
A.147	$V_{ECDRmaxLOW}$		I_{ECDR} = 10 µA	0		0.7	V
A.148	I_{ECDR}	Current into ECDR	V_{target}(3) > V_{ECV} + 500 mV; V_{ECDR} = 3.5 V	-100		-10	µA
A.149			V_{target}(3) < V_{ECV} - 500 mV; V_{ECDR} = 1.0 V; V_{target} = 0 V; V_{ECV} = 0.5 V	10		100	µA
A.150	$R_{ecdrdis}$	Pull-down resistance at ECDR in fast discharge mode and while EC-mode is off	V_{ECDR} = 0.7 V; ECON = '1', EC<5:0> = 0 or ECON = '0'			10	kΩ

1. Bit ECV_HV (Config Reg) ='1' or '0': ECV voltage, where I_{ECDR} can change sign.
2. 1 LSB (Least Significant Bit) = 23.8 mV typ.
3. V_{target} is set by bits EC<5:0> (CR 11) and bit ECV_HV (Config Reg); tested for each individual bit.

3.4.21 Fail safe low-side switch

The voltages are referred to power ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_S ≤ 18 V; T_j = 40 °C to 150 °C, unless otherwise specified.

Table 28. Fail safe low-side switch

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.151	V_{OUT_max}	Max output voltage in case of missing supply	I_{OUT} = 1 mA; $V_S = V_{SREG}$ = 0 V		2	2.5	V

Table 28. Fail safe low-side switch (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.152	R_{DSON}	DC output resistance	I_{LOAD} = 250 mA; T_j = 25 °C		1.4		Ω
A.153			I_{LOAD} = 250 mA; T_j = 130°C			2.2	Ω
A.154	I_{OLimit}	Overcurrent limitation	8 V < V_S < 16 V	500		1500	mA
A.155	t_{ONHL}	Turn on delay time to 10% V_{OUT}				100	µs
A.156	t_{OFFLH}	Turn off delay time to 90% V_{OUT}				100	µs
A.157	t_{SCF}	Short circuit filter time	Tested by scan		64		µs
A.158	dV_{max}/dt	Maximum external applied slew rate on LSA_FSO and LSB_FSO without switching on LS	Guaranteed by design	60			V/µs

3.4.22 Wake up input WU

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_{SREG} ≤ 28 V; T_j = 40 °C to 150 °C, unless otherwise specified.

Table 29. Wake-up inputs

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.159	V_{WUthn}	Wake-up negative edge threshold voltage		0.4 V_{SREG}	0.45 V_{SREG}	0.5 V_{SREG}	V
A.160	V_{WUthp}	Wake-up positive edge threshold voltage		0.5 V_{SREG}	0.55 V_{SREG}	0.6 V_{SREG}	V
A.161	V_{HYST}	Hysteresis		0.05 V_{SREG}	0.1 V_{SREG}	0.15 V_{SREG}	V
A.162	t_{WU_stat}	Static wake filter time	Tested by scan		64		µs
A.163	I_{WU_stdby}	Input current in standby mode	V_{WU} < 1 V or V_{WU} > (V_{SREG} – 1.5 V)	5	30	60	µA
A.164	R_{WU_act}	Input resistor to GND in Active mode and in Standby mode during Wake-up input sensing		80	160	300	kΩ
A.165	t_{WU_cyc}	Cyclic wake filter time	Tested by scan		16		µs

3.4.23 High speed CAN transceiver

ISO 11898-2:2003 and ISO 11898-5:2007 compliant.

SAE J2284 compliant.

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin.

5.5 V ≤ V_{SREG} ≤ 18 V; V_{CANSUP} = V1; $T_{junction}$ = -40 °C to 150 °C, unless otherwise specified.
-12 V ≤ (V_{CANH} + V_{CANL}) / 2 ≤ 12 V

Table 30. CAN communication operating range

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.001	V_{SREG_COM}	Supply voltage operating range for CAN communication	V_{V1} = V_{CANSUP}	5.5		18	V
E.002	$V_{CANSUPlow}$	CAN supply low voltage flag	V_{V1} = V_{CANSUP} decreasing	4.1	4.3	4.5	V
E.003	$V_{CANHL,CM}$	Common mode Bus voltage	Measured with respect to the ground of each CAN node	-12		12	V

Table 31. CAN transmit data input: pin TxD_C

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.004	$V_{TXDCLOW}$	Input voltage dominant level		1.0	1.45	2.0	V
E.005	$V_{TXDCHIGH}$	Input voltage recessive level		1.2	1.85	2.3	V
E.006	$V_{TXDCHYS}$	$V_{TXDCHIGH}$-$V_{TXDCLOW}$		0.2	0.4	0.7	V
E.007	R_{TXDCPU}	TXD_C pull up resistor		16	35	60	kΩ
E.008	$t_{d,TXDC(dom-rec)}$	TXDC - $CAN_{H,L}$ delay time dominant - recessive	R_L = 60 Ω; C_L = 100 pF; 70% V_{RXD} – 30% V_{DIFF}; TXDC rise time = 10 ns (10% - 90%)(1)	0		120	ns
E.009	$t_{d,TXDC(rec-diff)}$	TXDC - $CAN_{H,L}$ delay time recessive - dominant	R_L = 60 Ω; C_L = 100 pF; 30% V_{RXD} – 70% V_{DIFF}; TXDC fall time = 10 ns (90% - 10%)(1)	0		120	ns
E.010	$t_{dom(TXDC)}$	TXDC dominant time-out	Tested by scan	0.8	2	5	ms

1. Guaranteed by design.

Table 32. CAN receive data output: Pin RxD_C

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.011	$V_{RXDCLOW}$	Output voltage dominant level	I_{RXDC} = 2 mA	0	0.2	0.5	V
E.012	$V_{RXDCHIGH}$	Output voltage recessive level	I_{RXDC} = -2 mA	V1 - 0.5	V1 - 0.2	V1	V
E.013	$t_{r,RXDC}$	RxD_C rise time	C_L = 15 pF; 30% - 70% V_{RXDC} (1)	0		25	ns
E.014	$t_{f,RXDC}$	RxD_C fall time	C_L = 15 pF; 30% - 70% V_{RXDC} (1)	0		25	ns

Table 32. CAN receive data output: Pin RxD_C (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.015	$t_{d,RXDC(dom-rec)}$	$CAN_{H,L}$ – RXDC delay time dominant - recessive	C_L = 15 pF; 30% - 70% V_{RXDC} (1)	0		120	ns
E.016	$t_{d,RXDC(rec-dom)}$	$CAN_{H,L}$ – RXDC delay time recessive - dominant	C_L = 15 pF; 30% - 70% V_{RXDC} (1)	0		120	ns

1. Guaranteed by design.

Table 33. CAN transmitter dominant output characteristics

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.017	$V_{CANHdom}$	Single ended CANH voltage level in dominant state	V_{TXDC} = $V_{TXDCLOW}$; R_L = 50 Ω; 65 Ω	2.75	3.5	4.5	V
E.018	$V_{CANLdom}$	Single ended CANL voltage level in dominant state	V_{TXDC} = $V_{TXDCLOW}$; R_L = 50 Ω; 65 Ω	0.5	1.5	2.25	V
E.019	$V_{DIFF,dom}$	Differential output voltage in dominant state: $V_{CANHdom}$- $V_{CANLdom}$	V_{TXDC} = $V_{TXDCLOW}$; R_L = 50 Ω; 65 Ω	1.5	2.0	3	V
E.020	V_{SYM}	Driver symmetry V_{SYM} = $V_{CANHdom}$ + $V_{CANLdom}$	Measured over one 250 kHz period (4 µs) R_L = 50 Ω; 65 Ω; f_{TXDC} = 250 kHz (square wave, 50% duty cycle); (1) C_{SPLIT} = 4.7 nF (+-5%)	4.5	5	5.5	V
E.021	$I_{OCANH,dom\ (0V)}$	CANH output current in dominant state	V_{TXDC} = $V_{TXDCLOW}$; V_{CANH} = 0 V	-100	-75	-45	mA
E.022	$I_{OCANL,dom\ (5V)}$	CANL output current in dominant state	V_{TXDC} = $V_{TXDCLOW}$; V_{CANL} = 5 V	45	75	100	mA
E.023	$I_{OCANH,dom\ (40V)}$	CANH output current in dominant state	V_{TXDC} = $V_{TXDCLOW}$; V_{CANH} = 40 V; R_L = 65 Ω; V_S = 40 V	0		5	mA
E.024	$I_{OCANL,dom\ (40V)}$	CANL output current in dominant state	V_{TXDC} = $V_{TXDCLOW}$; V_{CANL} = 40 V; R_L = 65 Ω; V_S = 40 V	0		100	mA

1. Measurement equipment input load <20 pF, >1 MΩ.

Table 34. CAN transmitter recessive output characteristics, CAN normal mode

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.025	$V_{CANHrec}$	CANH voltage level in recessive state	TRX ready state; V_{TXDC} = $V_{TXDCHIGH}$; No load	2	2.5	3	V
E.026	$V_{CANLrec}$	CANL voltage level in recessive state	TRX Ready state; V_{TXDC} = $V_{TXDCHiGH}$; No load	2	2.5	3	V
E.027	$V_{DIFF,recOUT}$	Differential output voltage in recessive state $V_{CANHrec}$-$V_{CANLrec}$	TRX Ready state; V_{TXDC} = $V_{TXDCHIGH}$; No load	-50		50	mV

Note: CAN normal mode: tested in TRX ready state while the device is in active mode.

Table 35. CAN transmitter recessive output characteristics, CAN low-power mode, biasing active

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.028	$V_{CANHrecLPbias}$	CANH voltage level in recessive state	TRX BIAS state; V_{TXDC} = $V_{TXDCHIGH}$; No load	2	2.5	3	V
E.029	$V_{CANLrecLPbias}$	CANL voltage level in recessive state	TRX BIAS state; V_{TXDC} = $V_{TXDCHiGH}$; No load	2	2.5	3	V
E.030	$V_{DIFF,recOUTLPbias}$	Differential output voltage in recessive state $V_{CANHrec}$-$V_{CANLrec}$	TRX BIAS state; V_{TXDC} = $V_{TXDCHIGH}$; No load	-50		50	mV

Note: CAN low power mode, biasing active: tested in TRX BIAS state while the device is in active mode, V1_Standby mode and VBAT_Standby mode.

Table 36. CAN transmitter recessive output characteristics, CAN low-power mode, biasing inactive

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.031	$V_{CANHrecLP}$	CANH voltage level in recessive state	TRX Sleep state; V_{TXDC} = $V_{TXDCHIGH}$; No load	-0.1	0	0.1	V
E.032	$V_{CANLrecLP}$	CANL voltage level in recessive state	TRX Sleep state; V_{TXDC} = $V_{TXDCHIGH}$; No load	-0.1	0	0.1	V
E.033	$V_{DIFF,recOUTLP}$	Differential output voltage in recessive state $V_{CANHrec}$ - $V_{CANLrec}$	TRX Sleep state; V_{TXDC} = $V_{TXDCHIGH}$; No load	-50		50	mV

Note: CAN Low Power mode, biasing inactive: tested in TRX sleep state while the device is in active mode, V1_Standby mode and VBAT_Standby mode.

Table 37. CAN receiver input characteristics during CAN normal mode

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.034	V_{THdom}	Differential receiver threshold voltage recessive to dominant state	TRX ready state; (V_{CANH} + V_{CANL}) / 2 = -12 V, 2.5 V, 12 V(1)	0.5	—	0.9	V
E.035	V_{THrec}	Differential receiver threshold voltage dominant to recessive state	TRX Ready state; (V_{CANH} + V_{CANL}) / 2 = -12 V, 2.5 V, 12 V(1)	0.5	—	0.9	V

1. Parameter evaluated with specific R_L = 60 Ω; guaranteed by characterization.

Note: CAN normal mode: tested in TRX ready state while the device is in active mode.

Table 38. CAN receiver input characteristics during CAN low power mode, biasing active

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.036	$V_{THdomLPbias}$	Differential receiver threshold voltage recessive to dominant state	TRX BIAS state; (V_{CANH} + V_{CANL}) / 2 = -12 V, 2.5 V, 12 V(1)	0.5	—	0.9	V
E.037	$V_{THrecLPbias}$	Differential receiver threshold voltage dominant to recessive state	TRX BIAS state; (V_{CANH} + V_{CANL}) / 2 = -12 V, 2.5 V, 12 V(1)	0.5	—	0.9	V

1. Parameter evaluated with specific R_L = 60 Ω; guaranteed by characterization.

Note: CAN low power mode, biasing active: tested in TRX BIAS state while the device is in active mode, V1_Standby mode and VBAT_Standby mode.

Table 39. CAN Receiver input characteristics during CAN Low power mode, biasing inactive

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.038	$V_{THdomLP}$	Differential receiver threshold voltage recessive to dominant state	TRX sleep state; (V_{CANH} + V_{CANL}) / 2 = -12 V; 0 V; 12 V(1)	0.5	—	0.9	V
E.039	$V_{THrecLP}$	Differential receiver threshold voltage dominant to recessive state	TRX Sleep state; (V_{CANH} + V_{CANL}) / 2 = -12 V; 0 V; 12 V(1)	0.5	—	0.9	V

1. Parameter evaluated with specific R_L = 60 Ω; guaranteed by characterization.

Note: CAN Low Power mode, biasing inactive: Tested in TRX Sleep state while the device is in active mode, V1_Standby mode and VBAT_Standby mode.

Table 40. CAN receiver input resistance biasing active

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.040	R_{diff}	Differential internal resistance	TRX Ready & TRX BIAS states; V_{TXDC} = $V_{TXDCHIGH}$; no load	40	60	100	kΩ
E.041	$R_{CANH, CANL}$	Single ended Internal resistance	TRX Ready & TRX BIAS states; V_{TXDC} = $V_{TXDCHIGH}$; no load	20	30	50	kΩ
E.042	m_R	Internal Resistance matching $R_{CANH,CANL}$	TRX Ready & TRX BIAS states; V_{TXDC} = $V_{TXDCHIGH}$; no load; m_R = 2 x (R_{CAN_H} - R_{CAN_L}) / (R_{CAN_H} + R_{CAN_L})	-0.03		0.03	
E.043	C_{in}	Internal capacitance	Guaranteed by design		50		pF
E.044	$C_{in,diff}$	Differential internal capacitance	Guaranteed by design		10	20	pF

Note: CAN Normal and Low Power mode, biasing active: Tested in TRX Ready and TRX BIAS state while the device is in active and V1 Standby mode.

Table 41. CAN transceiver delay

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.045	$t_{TXpd,hl}$	Loop delay TxD_C to RxD_C (High to Low)	R_L = 60 Ω; C_L = 100 pF; 30% V_{TXDC} – 30% V_{RXDC}; TXDC fall time = 10 ns (90% - 10%); C_{RXDC} = 15 pF; f_{TXDC} = 250 kHz			255	ns
E.046	$t_{TXpd,lh}$	Loop delay TxD_C to RxD_C (Low to High)	R_L = 60Ω; C_L = 100pF; 70% V_{TXD} – 70% V_{RXD}; TXDC rise time = 10 ns (10% - 90%); C_{RXDC} = 15 pF; f_{TXDC} = 250 kHz			255	ns
E.047	T_{Bitrec}	Recessive Bit symmetry	R_L = 60 Ω; C_L = 100 pF; 70% V_{TXDC} (rising) - 30% V_{RXDC} (falling); C_{RXD} = 15 pF; 10 ns (10% - 90%, 90% - 10%); Rectangular pulse signal T_{TXDC} = 6000 ns, high pulse 1000 ns, low pulse 5000 ns	765	1000	1255	ns
E.048	t_{CAN}	CAN permanent dominant time-out	Tested by scan	500	700	1000	µs
E.049	t_{WUP-V1}(1)	Time between WUP(2) on the CAN bus until V1 goes active	Wake-Up according to ISO11898- 5:2007; 70% V_{DIFF} – 90% V1(min)	0		200	µs

1. Guaranteed by characterization.
2. Time starts with the end of last dominant phase of the WUP.

Table 42. Maximum leakage currents on CAN_H and CAN_L, unpowered

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.050	$I_{Leakage, CANH}$	Input leakage current CANH	Unpowered device; V_{CANH} = 5 V; V_{CANL} = 5 V; V_{SREG}, V_{CANSUP} connected via 0 Ω to GND; V_{SREG}, V_{CANSUP} connected via 47 kΩ to GND(1) T_j = -40 °C to 105 °C(2)	-10		10	µA
E.051			T_j = 130 °C(3)	-12		12	
E.052	$I_{Leakage, CANL}$	Input leakage current CANL	Unpowered device; V_{CANH} = 5 V; V_{CANL} = 5 V; V_{SREG}, V_{CANSUP} connected via 0 Ω to GND; V_{SREG}, V_{CANSUP} connected via 47 kΩ to GND(1) T_j = -40 °C to 105 °C(2)	-10		10	µA
E.053			T_j = 130 °C(3)	-12		12	

1. Guaranteed by design.
2. 105°C is the maximum junction temperature of an unpowered device according to this test condition within the specified ambient temperature range.
3. Used for device test only.

Table 43. Biasing control timings

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.054	t_{filter}	CAN activity filter time	Tested by scan	0.5		5	µs
E.055	t_{wake}	Wake-up time out	Tested by scan	0.5	1	5	ms
E.056	$t_{Silence}$	CAN timeout	Tested by scan	600	700	1200	ms
E.057	t_{BIAS}	Bias reaction time	R_L = 50 Ω, 65 Ω; C_L = 100 pF; C_{GND} (= C_{SPLIT}) = 100 pF; V_{TXDC} = $V_{TXDCLOW}$; 50% V_{DIFF} - V_{CANH} =V_{CANL} = $V_{CAN(H,L)rec(min)}$(1); Transition TRX Sleep to TRX BIAS in Active, V1_Standby and VBAT_Standby modes	0		200	µs

1. A wake-up-pattern is sent with a bit length of t_{filter}. T_{BIAS} is measured from the rising edge after having released the bus at the end of the 2nd dominant bit until CANH and CANL reach the minimum recessive output voltage ($V_{CANHrec}$, $V_{CANHrec}$).

3.4.24 LIN transceiver

LIN 2.2 compliant for bit-rates up to 20 kbit/s SAE J2602 compatible.

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_{SREG} ≤ 18 V; $T_{junction}$ = -40 °C to 150°C unless otherwise specified.

Table 44. LIN transmit data input: pin TxD_L

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.058	V_{TXDLOW}	Input voltage dominant level	Active mode	1.0			V
E.059	$V_{TXDHIGH}$	Input voltage recessive level	Active mode			2.3	V
E.060	V_{TXDHYS}	$V_{TXDHIGH}$-V_{TXDLOW}	Active mode	0.2			V
E.061	R_{TXDPU}	TXD pull up resistor	Active mode	13	29	46	kΩ

Table 45. LIN receive data output: pin RxD_L

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.062	V_{RXDLOW}	Output voltage dominant level	Active mode		0.2	0.5	V
E.063	$V_{RXDHIGH}$	Output voltage recessive level	Active mode	V1-0.5	V1-0.2		V

Table 46. LIN transmitter and receiver: pin LIN

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.064	V_{THdom}	Receiver threshold voltage recessive to dominant state		0.4 V_{SREG}	0.45 V_{SREG}	0.5 V_{SREG}	V
E.065	V_{Busdom}	Receiver dominant state				0.4 V_{SREG}	V
E.066	V_{THrec}	Receiver threshold voltage dominant to recessive state		0.5 V_{SREG}	0.55 V_{SREG}	0.6 V_{SREG}	V
E.067	V_{Busrec}	Receiver recessive state		0.6 V_{SREG}			V
E.068	V_{THhys}	Receiver threshold hysteresis: V_{THrec} - V_{THdom}		0.07 V_{SREG}	0.1 V_{SREG}	0.175 V_{SREG}	V
E.069	V_{THcnt}	Receiver tolerance center value: (V_{THrec} +V_{THdom})/2		0.475 V_{SREG}	0.5 V_{SREG}	0.525 V_{SREG}	V
E.070	V_{THwkup}	Activation threshold for wake-up comparator		1.0	1.5	2	V
E.071	$V_{THwkdwn}$	Activation threshold for wake-up comparator		V_{SREG} - 3.5	V_{SREG} - 2.5	V_{SREG} - 1.5	V
E.072	t_{LINBUS}	LIN Bus Wake-up Dominant Filter time	Sleep mode; edge: rec-dom; Tested by scan		64		µs
E.073	t_{dom_LIN}	LIN Bus Wake-up Dominant Filter time	Sleep mode; edge: rec-dom-rec; Tested by scan	28			µs
E.074	$I_{LINDomSC}$	Transmitter input current limit in dominant state	V_{TXD} = V_{TXDLOW}; V_{LIN} = V_{BATMAX} = 18 V	40	100	180	mA

Table 46. LIN transmitter and receiver: pin LIN (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.075	$I_{bus\_PAS\_dom}$	Input leakage current at the receiver incl. pull-up resistor	$V_{TXD} = V_{TXDHIGH}$; V_{LIN} = 0 V; V_{BAT} = 12 V; Slave mode	-1			mA
E.076	$I_{bus\_PAS\_rec}$	Transmitter input current in recessive state	In standby modes; $V_{TXD} = V_{TXDHIGH}$; V_{LIN} > 8 V; V_{BAT} < 18 V; $V_{LIN} \geq V_{BAT}$			20	µA
E.077	$I_{bus\_NO\_GND}$	Input current if loss of GND at device	GND = V_{SREG}; 0 V < V_{LIN} < 18 V; V_{BAT} = 12 V	-1		1	mA
E.078	I_{bus}	Input current if loss of V_{BAT} at device	GND = V_S; 0 V < V_{LIN} < 18 V Tj = -40 °C...105 °C(1)			30	µA
E.079			GND = V_S; 0 V < V_{LIN} < 18 V Tj = 130°C(2)			35	µA
E.080	V_{LINdom}	LIN voltage level in dominant state	Active mode; $V_{TXD} = V_{TXDLOW}$ RBus=500 Ohm			1.2	V
E.081	V_{LINrec}	LIN voltage level in recessive state	Active mode; $V_{TXD} = V_{TXDHIGH}$; I_{LIN} = 10 µA	0.8*V_S			V
E.082	R_{LINup}	LIN output pull up resistor	V_{LIN} = 0 V	20	40	60	kΩ
E.083	C_{LIN}	LIN input capacitance				30	pF

1. 105°C is the maximum junction temperature of an unpowered device according to this test condition within the specified ambient temperature range.
2. Used for device test only.

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6V ≤ V_S ≤ 28V; T_j = -40 °C to 150 °C, unless otherwise specified.

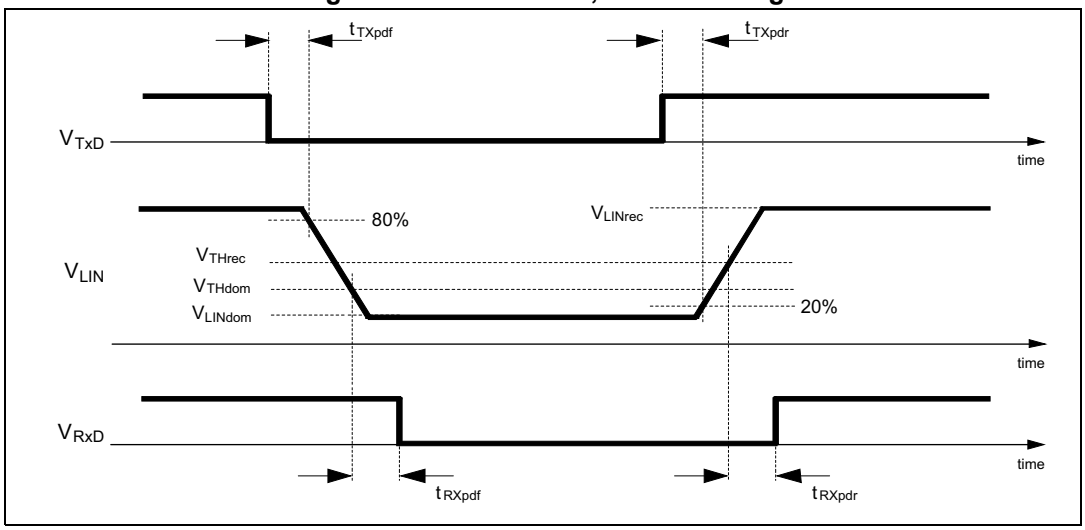
Table 47. LIN transceiver timing

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.084	t_{RXpd}	Receiver propagation delay time	t_{RXpd} = max (t_{RXpdr}, t_{RXpdf}); t_{RXpdf} = t(0.5 V_{RXD})-t(0.45 V_{LIN}); t_{RXpdr} = t(0.5 V_{RXD})-t(0.55 V_{LIN}); V_{SREG} = 12 V; C_{RXD}=20 pF; R_{bus} = 1 kΩ, C_{bus} = 1 nF; R_{bus} = 660 Ω, C_{bus} = 6.8 nF; R_{bus} = 500 Ω, C_{bus} = 10 nF			6	µs
E.085	t_{RXpd_sym}	Symmetry of receiver propagation delay time (rising vs. falling edge)	t_{RXpd_sym} = t_{RXpdr} - t_{RXpdf}; V_{SRE} = 12 V; R_{bus} = 1 kΩ; C_{bus} = 1 nF; C_{RXD} = 20 pF	-2		2	µs

Table 47. LIN transceiver timing (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
E.086	D1	Duty Cycle 1	$TH_{Rec}(max) = 0.744 * V_{SREG}$; $TH_{Dom}(max) = 0.581 * V_{SREG}$; V_{SREG} = 7 to 18 V, t_{bit} = 50 µs; D1 = $t_{bus\_rec}(min) / (2 \times t_{bit})$; R_{bus} = 1 kΩ, C_{bus} = 1 nF; R_{bus} = 660 Ω, C_{bus} = 6.8 nF; R_{bus} = 500 Ω, C_{bus} = 10 nF	0.396			
E.087	D2	Duty Cycle 2	$TH_{Rec}(min) = 0.422 * V_{SREG}$; $TH_{Dom}(min) = 0.284 * V_{SREG}$; V_{SREG} = 7.6 to 18 V, t_{bit} = 50 µs; D2 = $t_{bus\_rec}(max) / (2 \times t_{bit})$; R_{bus} = 1 kΩ, C_{bus} = 1 nF; R_{bus} = 660 Ω, C_{bus} = 6.8 nF; R_{bus} = 500 Ω, C_{bus} = 10 nF			0.581	
E.088	D3	Duty Cycle 3	$TH_{Rec}(max) = 0.778 * V_{SREG}$; $TH_{Dom}(max) = 0.616 * V_{SREG}$; V_{SREG} = 7 to 18 V, t_{bit} = 96 µs; D3 = $t_{bus\_rec}(min) / (2 \times t_{bit})$; R_{bus} = 1 kΩ, C_{bus} = 1 nF; R_{bus} = 660 Ω, C_{bus} = 6.8 nF; R_{bus} = 500 Ω, C_{bus} = 10 nF	0.417			
E.089	D4	Duty Cycle 4	$TH_{Rec}(min) = 0.389 * V_{SREG}$; $TH_{Dom}(min) = 0.251 * V_{SREG}$; V_{SREG} = 7.6 to 18 V, t_{bit} = 96 µs; D4 = $t_{bus\_rec}(max) / (2 \times t_{bit})$; R_{bus} = 1 kΩ, C_{bus} = 1 nF; R_{bus} = 660 Ω, C_{bus} = 6.8 nF; R_{bus} = 500 Ω, C_{bus} = 10 nF			0.590	
E.090	$t_{dom(TXDL)}$	TXD_L dominant time-out	Tested by scan		12		ms
E.091	t_{LIN}	LIN permanent recessive time-out	Tested by scan		40		µs
E.092	$t_{dom(bus)}$	LIN Bus permanent dominant time-out	Tested by scan		12		ms

Figure 12. LIN transmit, receive timing



3.4.25 SPI

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V < V_{SREG} < 18 V; V1 = 5 V; all outputs open; T_j = -40 °C to 150 °C, unless otherwise specified.

Table 48. Input: CSN

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.001	V_{CSNLOW}	Input voltage low level	Normal mode	1.0			V
B.002	$V_{CSNHIGH}$	Input voltage high level	Normal mode			2.3	V
B.003	V_{CSNHYS}	$V_{CSNHIGH}$ - V_{CSNLOW}	Normal mode	0.2			V
B.004	I_{CSNPU}	CSN Pull up resistor	Normal mode	13	29	46	kΩ

Table 49. Inputs: CLK, DI

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.005	t_{set}	Delay time from standby to Active mode	Time until SPI, ADC and OUT15 are operative		10		µs
B.006	t_{set_CP}	Delay time from standby to Active mode	Time until power stages that are supplied by the CP are operative	560	750	960	µs
B.007	V_{in_L}	Input low level		1.0			V
B.008	V_{in_H}	Input high level				2.3	V
B.009	V_{in_Hyst}	Input hysteresis		0.2			V
B.010	I_{pdin}	Pull down current at input	V_{in} = 1.5 V	5	30	60	µA

Table 49. Inputs: CLK, DI (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.011	C_{in}(1)	Input capacitance at input CSN, CLK, DI	Guaranteed by design			15	pF
B.012	f_{CLK}	SPI input frequency at CLK	Tested by scan			4	MHz

1. Value of input capacity is not measured in production test. Parameter guaranteed by design.

Table 50. DI, CLK and CSN timing

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.013	t_{CLK}	Clock period	Tested by scan	250			ns
B.014	t_{CLKH}	Clock high time		100			ns
B.015	t_{CLKL}	Clock low time		100			ns
B.016	t_{set_CSN}	CSN setup time, CSN low before rising edge of CLK		150			ns
B.017	t_{set_CLK}	CLK setup time, CLK high before rising edge of CSN		150			ns
B.018	t_{set_DI}	DI setup time		25			ns
B.019	t_{hold_DI}	DI hold time		25			ns
B.020	t_{r_in}	Rise time of input signal DI, CLK, CSN				25	ns
B.021	t_{f_in}	Fall time of input signal DI, CLK, CSN				25	ns

Note: See Figure 14: SPI input timing.

Table 51. Output: DO

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.022	V_{DOL}	Output low level	I_{DO} = + 4 mA			0.5	V
B.023	V_{DOH}	Output high level	I_{DO} = - 4 mA	V1 - 0.5			V
B.024	I_{DOLK}	3-state leakage current	V_{CSN} = V1, 0 V < V_{DO} < V1	-10		10	µA
B.025	C_{DO}	3-state input capacitance	Guaranteed by design		10	15	pF

Table 52. DO timing

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.026	$t_{r\ DO}$	DO rise time	C_L = 50 pF; I_{LOAD} = -1 mA	-		25(1)	ns
B.027	$t_{f\ DO}$	DO fall time	C_L = 50 pF; I_{LOAD} = +1 mA	-		25(1)	ns

Table 52. DO timing (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.028	$t_{en\ DO\ tri\ L}$	DO enable time from CSN falling edge: 3-state to low level on DO	C_L = 50 pF; I_{LOAD} = +1 mA; pull-up load to V1	-	50	100	ns
B.029	$t_{dis\ DO\ L\ tri}$	DO disable time from CSN rising edge: low level to 3-state on DO	C_L = 50 pF; I_{LOAD} = +1 mA; pull-up load to V1	-	50	100	ns
B.030	$t_{en\ DO\ tri\ H}$	DO enable time from CSN falling edge: 3-state to high level on DO	C_L = 50 pF; I_{LOAD} = +1 mA; pull-up load to V1	-	50	100	ns
B.031	$t_{dis\ DO\ H\ tri}$	From CSN rising with DO at high level to 3-states measured at 0.3 V1	C_L = 50 pF; I_{LOAD} = -1 mA; pull-down load to GND	-	50	100	ns
B.032	$t_{d\ DO}$	DO delay time	V_{DO} < 0.3 V1; V_{DO} > 0.7 V1; C_L = 50 pF	-	30	60	ns

1. Guaranteed by design.

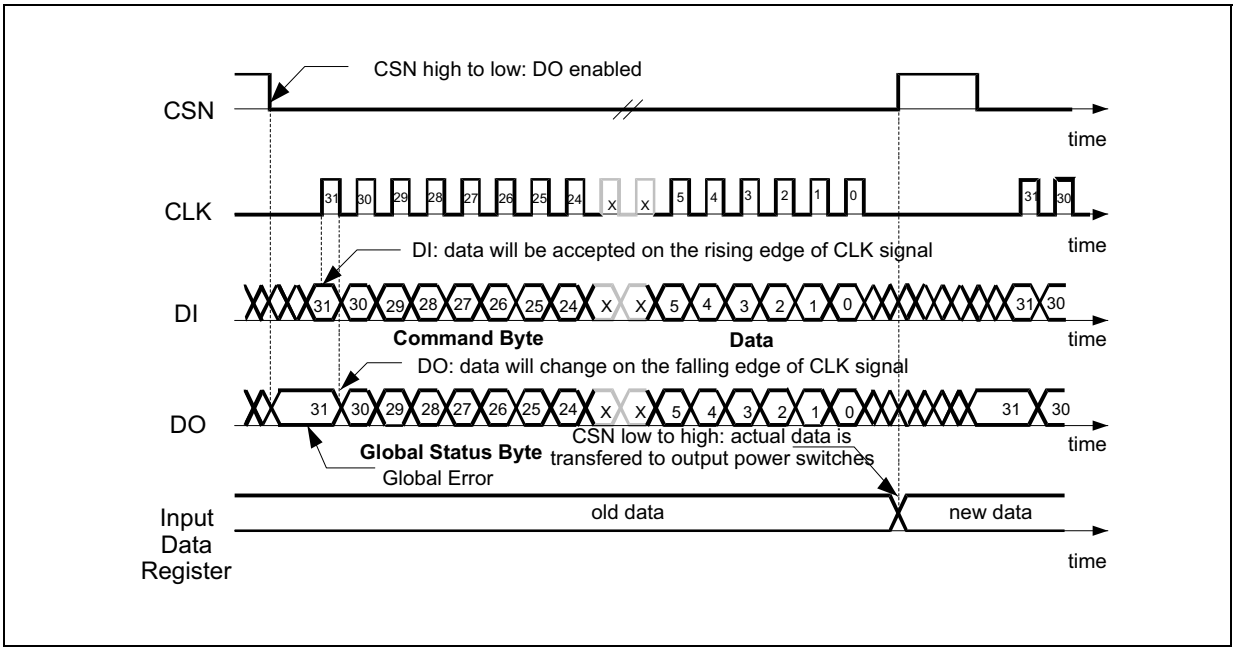
Note: *See Figure 15: SPI output timing.*

Table 53. CSN timing

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
B.033	$t_{CSN\_HI,min}$	Minimum CSN High time, active mode	Transfer of SPI-command to Input Register	6			µs
B.034	$t_{CSNfail}$	CSN low timeout	Tested by scan	20	35	50	ms

Note: *See Figure 15: SPI output timing.*

Figure 13. SPI – transfer timing diagram



The SPI can be driven by a microcontroller with its SPI peripheral running in following mode: CPOL = 0 and CPHA = 0. For this mode input data is sampled by the low to high transition of the clock CLK, and output data is changed from the high to low transition of CLK.

Figure 14. SPI input timing

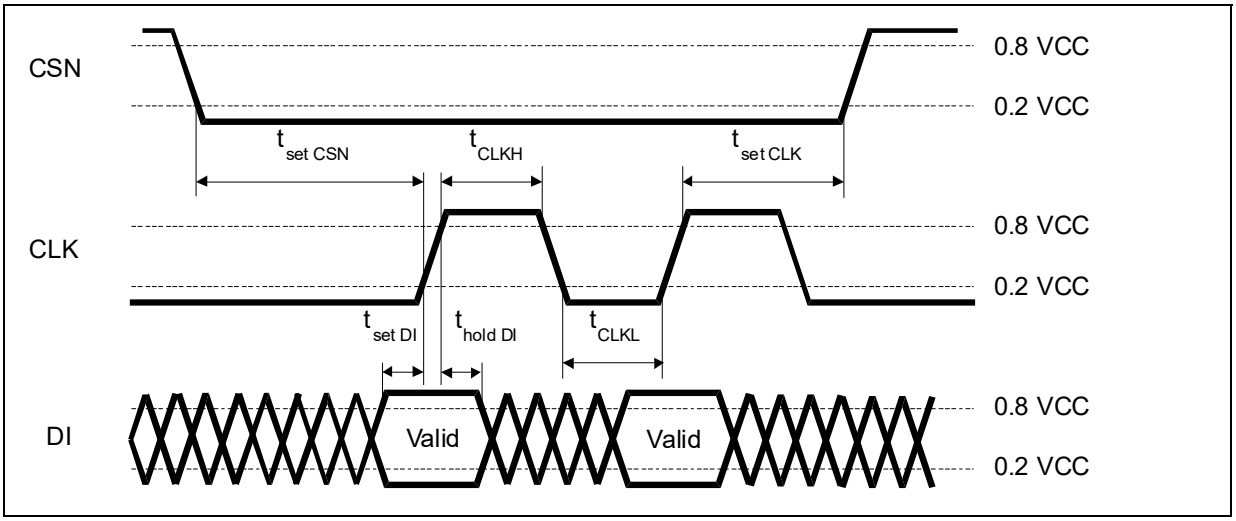


Figure 15. SPI output timing

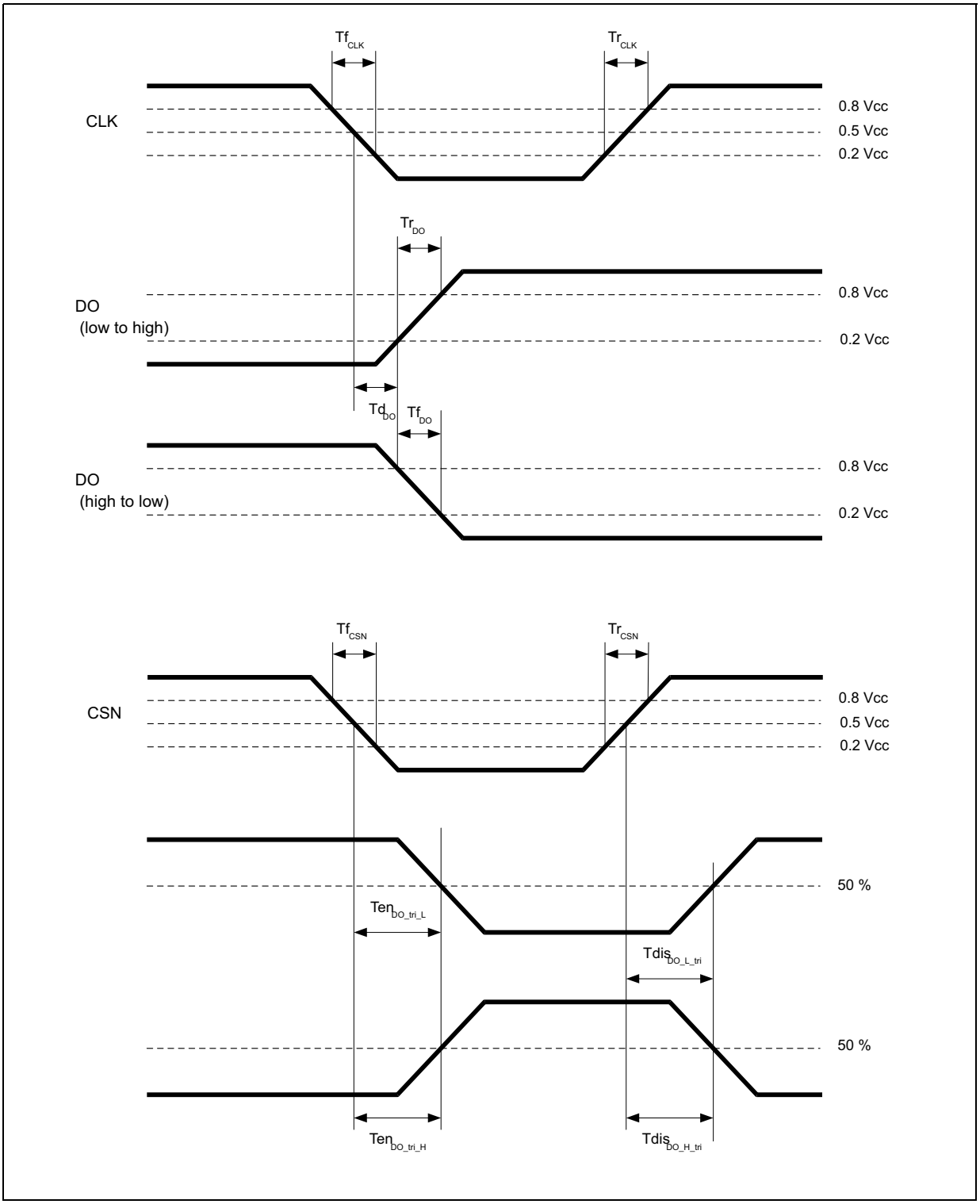


Figure 16. SPI CSN - output timing

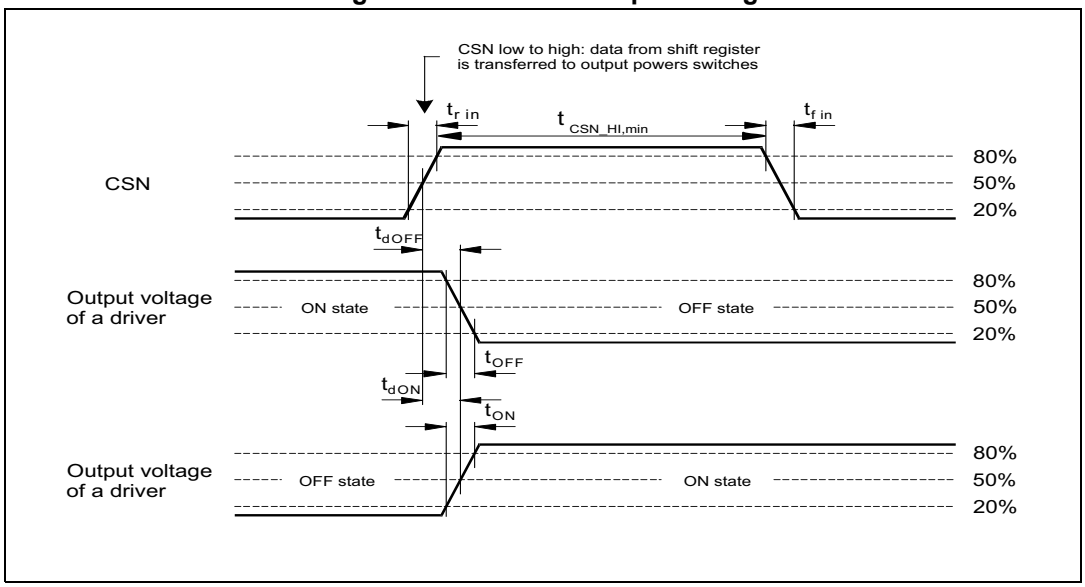
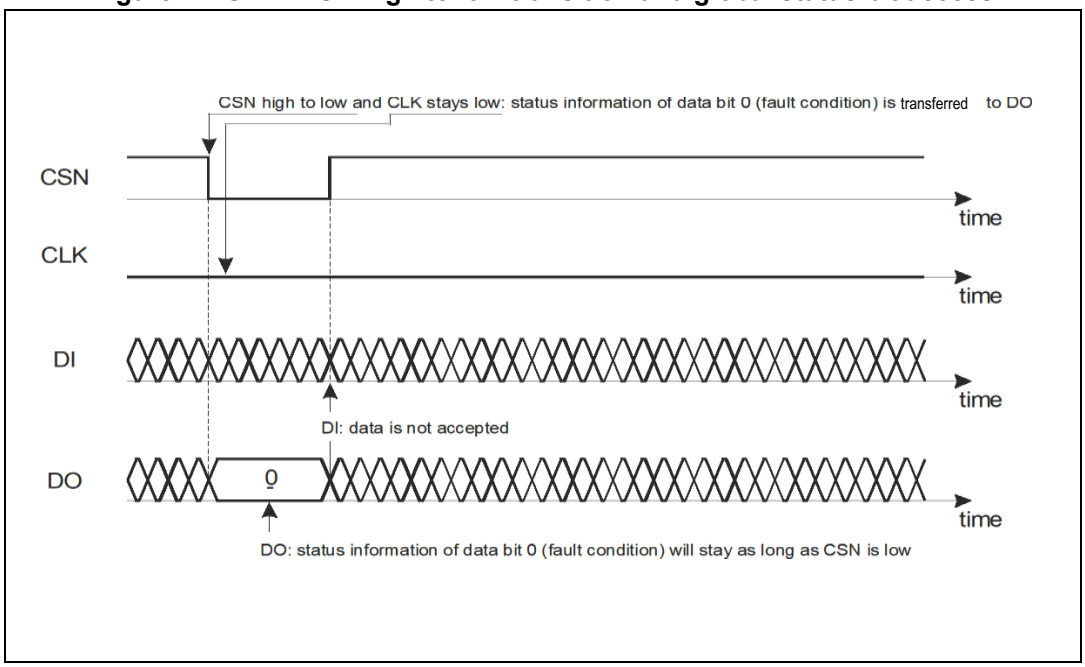


Figure 17. SPI – CSN high to low transition and global status bit access



3.4.26 Inputs TxD_C and TxD_L for Flash mode

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6V ≤ V_{SREG} ≤ 18; V1 = 5 V; T_j = -40 °C to 150 °C.

Table 54. Inputs: TxD_C and TxD_L for Flash mode

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.166	V_{flashL}	Input low level ($V_{TXDC/L}$ for exit from Flash mode)	-	6.1	7.25	8.4	V
A.167	V_{flashH}	Input high level ($V_{TXDC/L}$ for transition into Flash mode)	-	7.4	8.4	9.4	V
A.168	$V_{flashHYS}$	Input voltage hysteresis	-	0.6	0.8	1.0	V

3.4.27 PWMH(1/2)A, PWMH(1/2)B and DIR inputs

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_{SREG} ≤ 18 V; T_j = -40 °C to 150 °C.

DIR Input refers to the CM_DIR pin when working as a Direct Drive Input (see *Section 4.22: Current monitor and direct drive input*).

Table 55. Inputs PWMH1A, PWMH2A, PWMH1B, PWMH2B, DIR

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.169	V_{IL}	Input voltage low level	V_{SREG} = 13.5 V	1			V
A.170	V_{IH}	Input voltage high level	V_{SREG} = 13.5 V			2.3	V
A.171	V_{IHYS}	Input hysteresis	V_{SREG} = 13.5 V	0.2			V
A.172	I_{in}	Input pull-down current	V_{SREG} = 13.5 V	5	30	60	µA
A.173	C_{in} (1)	Input capacitance at input PWMH1A, PWMH2A, PWMH1B and PWMH2B	Guaranteed by design			15	pF

1. Value of input capacitance is not measured in production test. Parameter guaranteed by design.

3.4.28 ADC characteristics

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_{SREG} ≤ 18 V, T_j = -40 °C to 150 °C.

Table 56. ADC characteristics

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
F.001	t_{con}	Conversion time	Tested by scan		3		µs
F.002	f_{ADC}	Clock frequency (see f_{clk2})	Tested by scan		8		MHz

Table 56. ADC characteristics (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
F.003	Acc	Accuracy	Voltage divider + reference(1)	-2		2	%
F.004			Overall accuracy for WU input: V_{WU} = 22 V	-3		3	
F.005			Overall accuracy for WU input: V_{WU} = 18 V	-3.5		3.5	
F.006			Overall accuracy for WU input: V_{WU} = 6 V	-4		4	
F.007			Overall accuracy for WU input: V_{WU} = 4.5 V	-4.6		4.6	
F.008	IEIl	Integral linearity error			4	6	LSB
F.009	IEDl	Differential linearity error			2	4	LSB
F.010	V_{AINVS}	Conversion voltage range (V_S, V_{SREG} & WU)		1		22	V
F.011	$V_{AINTemp}$	Conversion voltage range ($T_{CL}1$ …$T_{CL}6$)		0		2	V

1. Guaranteed by design.

3.4.29 Temperature diode characteristics

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_{SREG} ≤ 18 V, T_j = -40 °C to 150 °C

Table 57. Temperature diode characteristics

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.174	$V_{TROOM\ 1-6}$	T_{SENSE} output voltage at 25 °C	V_S = 12 V; T = 25 °C	—	1.4		V
A.175	$V_{TSENSE1-6}$	T_{SENSE} output voltage	T = 25 °C; T = 130 °C; T = -40 °C	—	-4		mV/K

3.4.30 Interrupt outputs

The voltages are referred to ground and currents are assumed positive, when the current flows into the pin. 6 V ≤ V_{SREG} ≤ 18 V, T_j = -40 °C to 150°C

Table 58. Interrupt outputs

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.176	V_{INTL}	Output low level	I_{INT} = +4 mA			0.5	V
A.177	V_{INTH}	Output high level	I_{INT} = -4 mA	V1 - 0.5			V
A.178	I_{INTLK}	3-state leakage current	0 V < V_{INT} < V1	-10		10	µA

Table 58. Interrupt outputs (continued)

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.179	$t_{Interrupt}$	Interrupt pulse duration (NINT, RxD_L/NINT, RxD_C/NINT	Tested by scan		56		µs
A.180	t_{Int_react}	Interrupt reaction time	Tested by scan	6		40	µs

3.4.31 Timer1 and Timer2

6 V ≤ V_{SREG} ≤ 18 V; T_j = -40 °C to 150 °C

Table 59. Timer1 and Timer2

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
F.012	ton 1	Timer on time	Tested by scan	-	0.1	-	ms
F.013	ton 2	Timer on time	Tested by scan	-	0.3	-	ms
F.014	ton 3	Timer on time	Tested by scan	-	1	-	ms
F.015	ton 4	Timer on time	Tested by scan	-	10	-	ms
F.016	ton 5	Timer on time	Tested by scan	-	20	-	ms
F.017	T1	Timer period	Tested by scan	-	10	-	ms
F.018	T2	Timer period	Tested by scan	-	20	-	ms
F.019	T3	Timer period	Tested by scan	-	50	-	ms
F.020	T4	Timer period	Tested by scan	-	100	-	ms
F.021	T5	Timer period	Tested by scan	-	200	-	ms
F.022	T6	Timer period	Tested by scan	-	500	-	ms
F.023	T7	Timer period	Tested by scan	-	1000	-	ms
F.024	T8	Timer period	Tested by scan	-	2000	-	ms

3.4.32 SGND loss comparator

T_j = -40 °C to 150 °C, unless otherwise specified

Table 60. SGND loss comparator

Item	Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
A.181	$V_{SGNDloss}$	V_{SGND} loss threshold	(V_{SGND} – V_{PGND})	200	420	650	mV
A.183	$V_{SGNDloss\_hys}$			40	70	150	mV
A.182	$t_{SGNDloss}$	V_{SGND} loss filter time	Tested by scan	-	7	-	µs

4 Application information

4.1 Supply V_S, V_{sreg}

V_{SREG} supplies voltage regulator V1, voltage tracker V2, all internal regulated voltages for analog and digital functionality, LIN, CAN, the EC control block and the P-channel high-side switch OUT15. All other high-sides, Fail Safe block and the charge pump are supplied by V_S. In case the V_{SREG} pin is disconnected, all power outputs connected to V_S are automatically switched off.

4.2 Voltage Regulators

The device contains two independent and fully protected low drop voltage regulators designed for very fast transient response and do not require electrolytic output capacitors for stability.

4.2.1 Voltage regulator: V1

The V1 voltage regulator provides 5 V supply voltage and up to 250 mA continuous load current to supply the system microcontroller and the integrated CAN transceiver. The V1 regulator is embedded in the power management and fail-safe functionality of the device and operates according to the selected operating mode. The V1 voltage regulator is supplied by pin V_{SREG}.

In addition, the V1 regulator supplies the devices internal loads. The voltage regulator is protected against overload and overtemperature. An external reverse current protection has to be provided by the application circuitry to prevent the input capacitor from being discharged by negative transients or low input voltage. Current limitation of the regulator ensures fast charge of external bypass capacitors. The output voltage is stable for ceramic load capacitors >220 nF.

In case the device temperature exceeds the TSD1 threshold (either cluster or grouped mode) the V1 regulator remains on. The microcontroller has the possibility for interaction or error logging. If the chip temperature exceeds the TSD2 threshold (TSD2 > TSD1), V1 will be deactivated and all wake-up sources (CAN, LIN, WU and Timer) are disabled. After t_{TSD}, the voltage regulator will restart automatically. If the restart fails 7 times within one minute the devices enter the Forced VBAT_Standby mode. The status bit FORCED_SLEEP_TSD2/V1SC (SR1) is set.

4.2.2 Voltage regulator: V2

The voltage regulator V2 can be configured by means of the V2_CONFIG bit in the Config Reg as a classical LDO (V2_CONFIG=0, default) or as a tracker of the V1 voltage regulator; when V2 is configured as Voltage Tracker of V1, it provides a 5V output that tracks the V1 regulator output voltage with +-20 mV accuracy with load currents up to 50 mA.

When V2 voltage regulator is configured in Tracking mode, the V1 Reset Threshold shall be configured to be the VRT1 (V1_RESET_1 = 1, V1_RESET_0 = 1 in CR2).

In both cases the V2 regulator is protected against:

- Overload
- Overtemperature
- Short-circuit (short to ground and battery supply voltage)
- Reverse biasing

4.2.3 Voltage Regulator Failure

The V1, and V2 regulator output voltages are monitored.

In case of a drop below the failure thresholds ($V1 < V1_{fail}$ for $t > t_{V1fail}$, $V2 < V2_{fail}$ [(a)] for $t > t_{V2fail}$), the failure bits V1FAIL, V2FAIL (SR 2) are latched.

4.2.4 Short to ground detection

At turn-on of the V1 and V2 regulators, a short-to-GND condition is detected by monitoring the regulator output voltage.

If V1 or V2 is below the $V1_{fail}$ (or $V2_{fail}$ [(a)]) threshold for $t > t_{V1short}$ ($t > t_{V2short}$ [(b)]) after turn-on, the devices will identify a short circuit condition and the related regulator will be switched off.

In case of V1 short-to-GND the device enters Forced VBAT_Standby mode automatically. Bits FORCED_SLEEP_TSD2/V1SC (SR 1) and V1FAIL (SR 2) are set.

In case of a V2 short-to-GND failure the V2SC (SR 2) and V2FAIL (SR 2) bits are set.

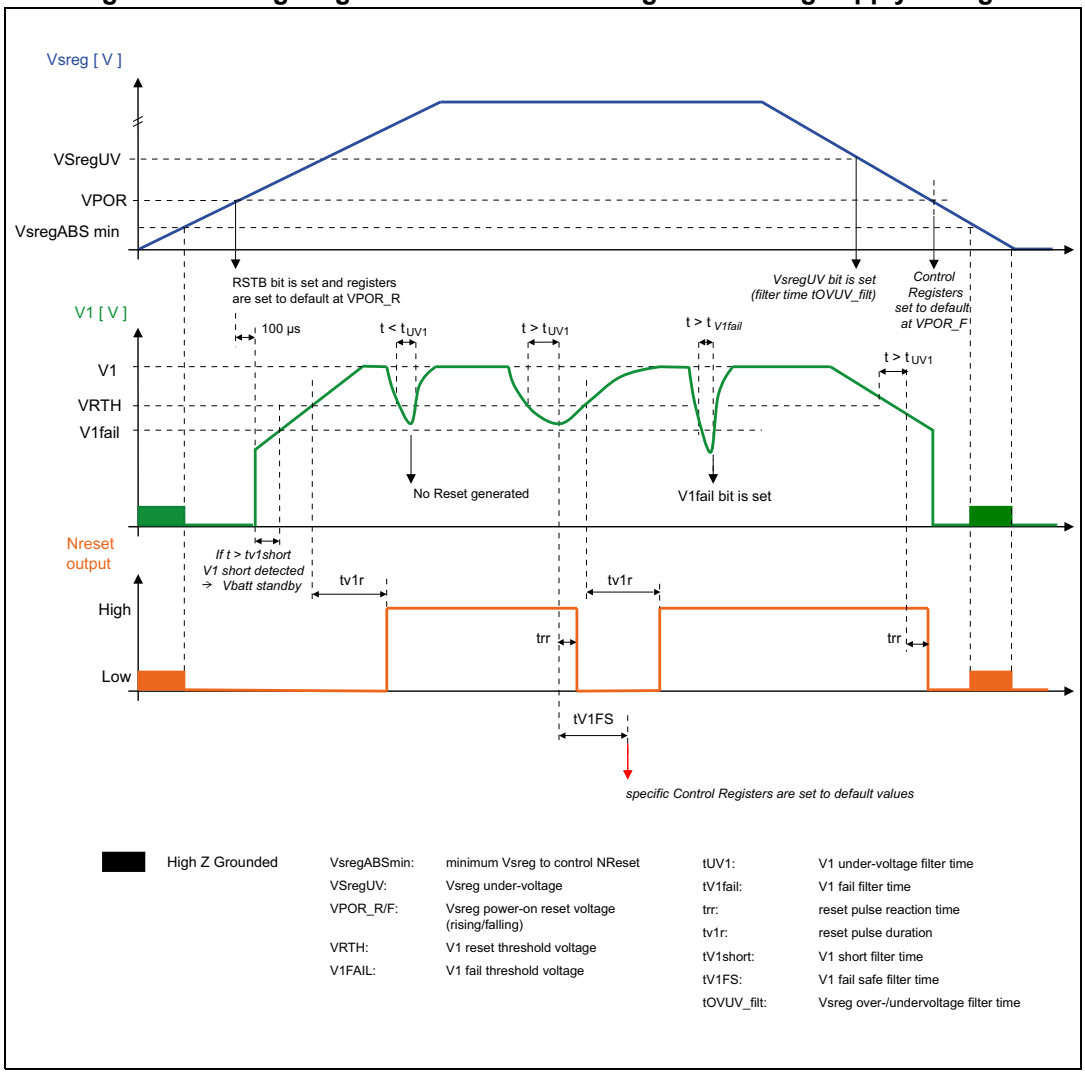
Once the output voltage of the corresponding regulator exceeded the $V1_{fail}$ ($V2_{fail}$[(a)]) threshold the short-to-ground detection is disabled. In case of a short-to-ground condition, the regulator is switched off due to thermal shutdown. V1 is switched off at TSD2, V2 is switched off at TSD1

a. $V2_{fail\_trk}$ in case of tracker.

b. $t > t_{V2short\_trk}$.

4.2.5 Voltage regulator behavior

Figure 18. Voltage regulator behavior and diagnosis during supply voltage



4.3 Operating Modes

The devices can be operated in the following operating modes:

- Active
- LIN Flash
- CAN Flash
- V1_Standby
- VBAT_Standby
- SW-Debug

4.3.1 Active Mode

All functions are available and the device is controlled by SPI.

4.3.2 Flash Modes

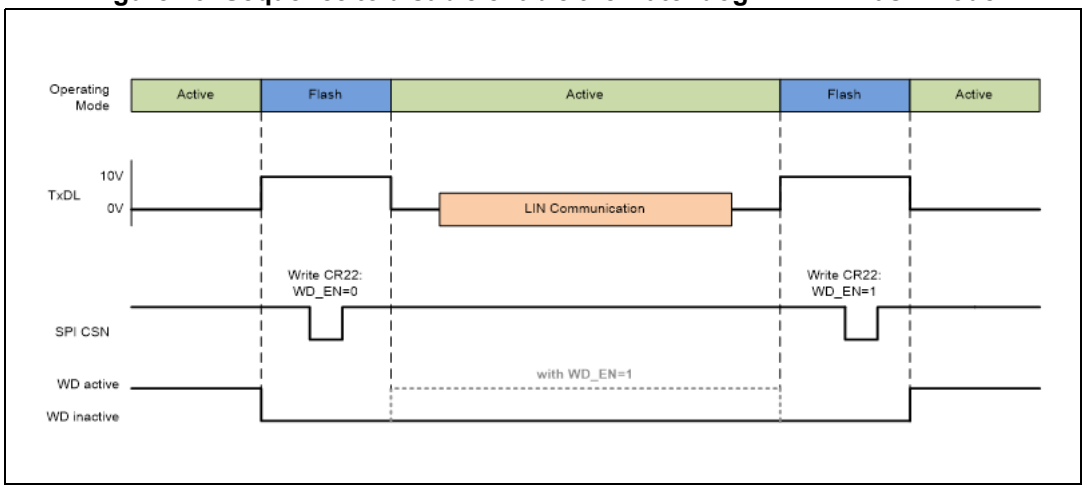
To program the system microcontroller via LIN or HS CAN bus signals, the devices can be operated in LIN Flash mode or CAN Flash mode. The watchdog is disabled in these modes.

The Flash modes are entered by applying an external voltage at the respective pin:

- $V_{TxDL} \geq V_{FlashH}$ (CAN Flash mode)
- $V_{TxDC} \geq V_{FlashH}$ (LIN Flash mode)

In CAN Flash mode the CAN transceiver is set in TRX READY mode (CAN_GO_TRX_RDY = 1) and TRX Normal mode automatically. During CAN Flash mode, the watchdog can be deactivated by setting CR22: WD_EN = 0. Write access to this bit is only possible during CAN Flash mode in order to prevent accidental deactivation of the watchdog. After setting WD_EN (CR 22) the CAN Flash mode can be left ($V_{TxDL} < V_{FlashL}$) and the Watchdog will remain deactivated (see *Figure 19*).

Figure 19. Sequence to disable/enable the watchdog in CAN Flash mode



In LIN Flash mode the maximum bitrate is increased to 100 kbit/s automatically (LIN_HS_EN = 1).

A transition from Flash modes to V1_Standby or VBAT_Standby mode is not possible.

At exit from Flash modes ($V_{TxDL} < V_{FlashL}$, $V_{TxDC} < V_{FlashL}$) no NReset pulse is generated. The watchdog starts with a Long Open Window (t_{LW}).

Note: Setting both TxD_L and TxD_C to high voltage levels (> V_{FlashH}) is not allowed. Communication at the respective TxD pin is not possible.

4.3.3 SW-Debug Mode

The SW-Debug mode is conceived to be used during the microcontroller debugging; in this mode, all the L99DZ200G functionalities and operating modes are available and the watchdog is deactivated easing the debug of the microcontroller firmware.

The DEBUG_ACTIVE bit (SR1) indicates if the L99DZ200G is in SW-Debug mode; it is recommended that the system microcontroller reads this bit after every cold start and wake-

up events in order to ensure which is the device mode (DEBUG_ACTIVE = 1 for SW-Debug mode, DEBUG_ACTIVE = 0 for Normal mode).

Enter procedure

To enter in SW-Debug mode, the watchdog can be deactivated by applying at the power rising a high-level voltage (5V) on the PWMH1B input pin; this procedure shall be done before the rising edge of the NRESET pin, in order to avoid any possible constraint for the application development. The high voltage on PWMH1B pin can be achieved by tying together both the V1 and the PWMH1B signals; after a time interval $\mathbf{t_{V1R}}$ (typ. 2 ms), once the PWMH1B signal is put low, the NRESET output rises at its highest value and the L99DZ200G is from now on in SW-Debug mode (see *Figure 20: Sequence to enter in SW-Debug mode*).

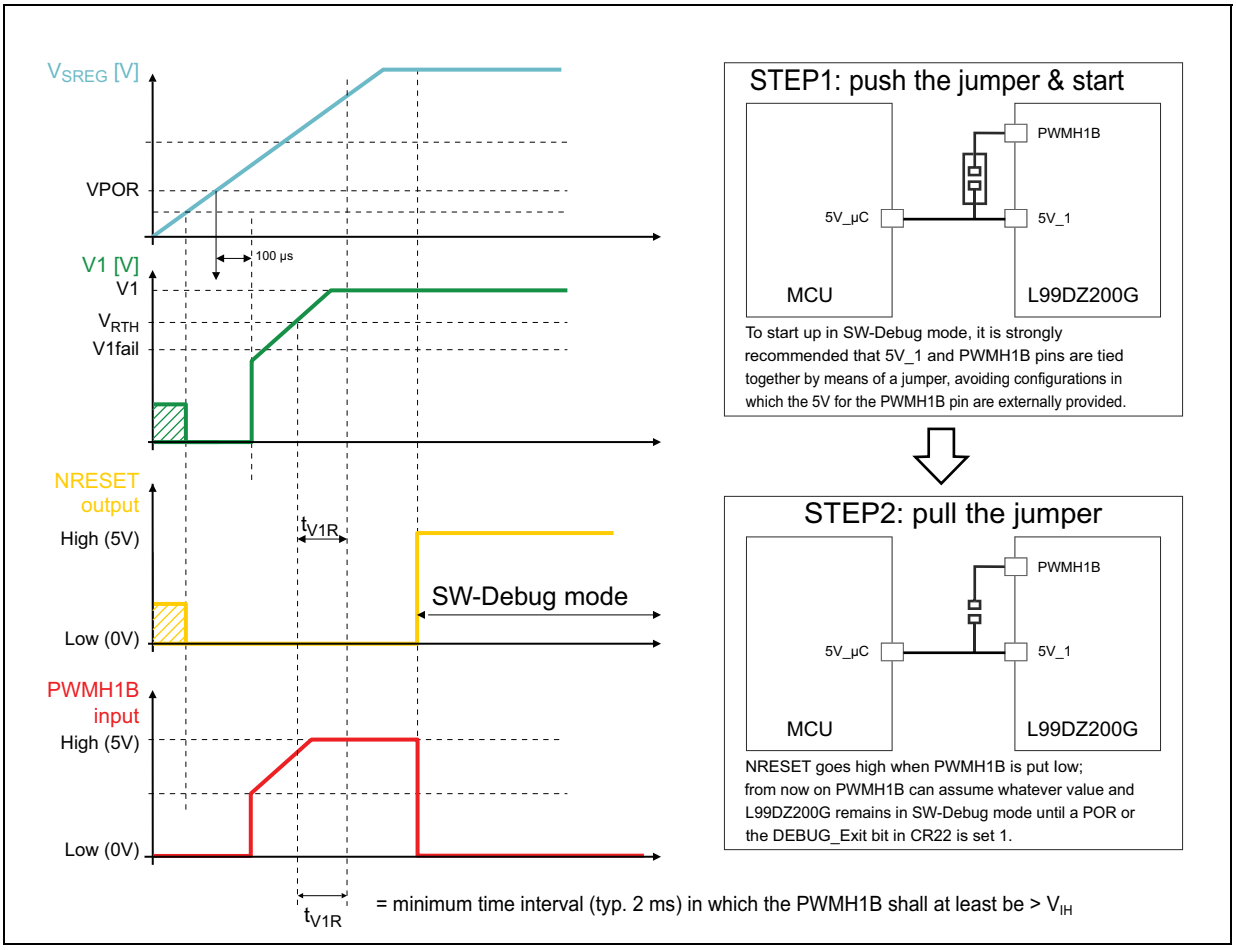
Exit procedure

When in SW-Debug mode, the microcontroller has the possibility to let the L99DZ200G exit from this mode by setting the DEBUG_EXIT bit in CR22.

When the L99DZ200G is in SW-Debug mode, if the DEBUG_EXIT bit is set to 1, it exits from SW-Debug mode and the watchdog starts a Long Open Window; in this case the DEBUG_EXIT bit remains fixed to 1 (even if the device is already in Normal mode) and the system microcontroller can clear it.

When the L99DZ200G is in Normal mode, setting DEBUG_EXIT bit does not produce any effect on the device.

Figure 20. Sequence to enter in SW-Debug mode



4.3.4 V1_Standby mode

The transition from Active mode to V1_Standby mode is controlled by SPI.

To supply the microcontroller in a low power mode, the V1 voltage regulator remains active.

After the V1_Standby command (CSN low to high transition), the device enters V1_Standby mode immediately and the watchdog starts a Long Open Window (t_{LW}). The watchdog is deactivated as soon as the V1 load current drops below the I_{CMP} threshold ($I_{V1} < I_{cmp\_fal}$).

The V1 load current monitoring can be deactivated by setting ICMP = 1. In this configuration the watchdog will be deactivated upon transition into V1_Standby mode without monitoring the V1 load current.

Writing ICMP (CR 34) = 1 is only possible with the first SPI command after setting ICMP_CONFIG_EN (Config Reg) = 1.

The ICMP_CONFIG_EN bit is reset to 0 automatically with the next SPI command.

Power outputs (except OUT15 [c]) are switched off in V1_Standby mode. OUT15 remains in the configuration programmed prior to the standby command in order to enable cyclic supply

c. This exception applies only if OUT15 is not driven with an internally generated PWM signal

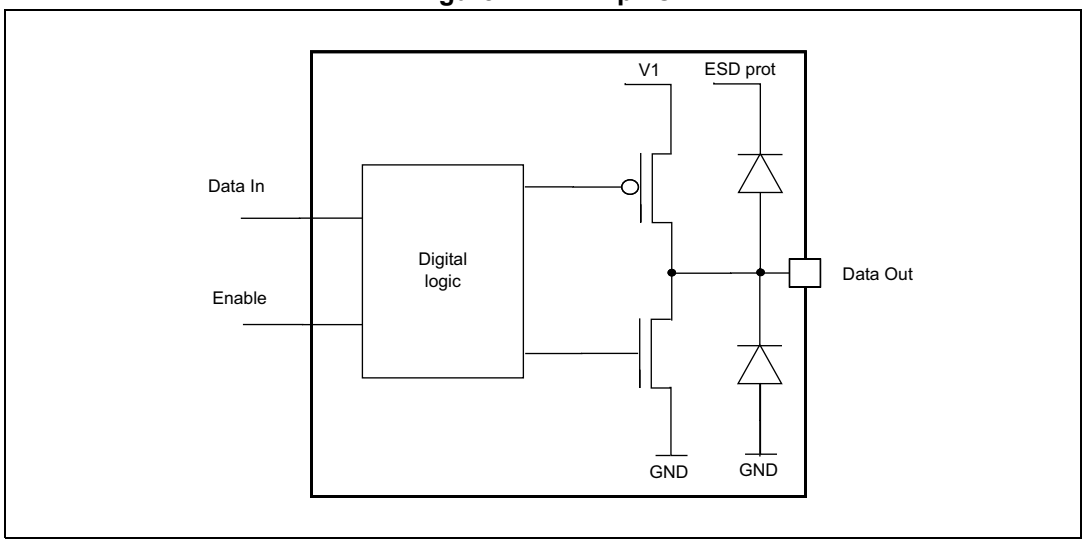
of external contacts. The timer signal (Timer1 or Timer2) can be mirrored to the NINT output pin during V1_Standby mode.

CAN and LIN transmitters (TxD_L, TxD_C) are off.

Wake-up capability by CAN and LIN can be disabled by SPI. The CAN transceiver can be configured in Listen mode (TxD_C disabled, RxD_C enabled) in order to support pretended networking concepts (for details see *Section 4.10.6: Pretended Networking*).

4.3.5 Interrupt

Figure 21. NINT pins



RxD_L/NINT indicates:

- a wake-up event from V1_Standby mode (except wake-up by CAN)
  RxD_L/NINT pin is pulled low for t = $t_{interrupt}$.

RxD_C/NINT indicates:

- Mode transitions of the CAN transceiver according to *Figure 30: CAN transceiver state diagram*
- CAN communication timeout (no CAN communication for t > $t_{Silence}$). The CANTO flag is set. This interrupt can be masked by SPI (CR1: CANTO_IRQ_EN).
  RxD_C/NINT pin is pulled low for t = $t_{interrupt}$. See also *Section 4.3.6: CAN wake-up signalization*

NINT indicates:

- In Active mode:
  V_{SREG} dropped below the programmed early warning threshold in Control Register 3 (V_{SREG} < VSREG_EW_TH); feature is deactivated if VSREG_EW_TH is set to 0 V.

In V1_Standby mode

  – Programmable timer interrupt; an NINT pulse is generated at the beginning of the timer on-time (Timer 1 or Timer2)
  – CAN communication timeout (no CAN communication for t > $t_{Silence}$). The CANTO flag is set. This interrupt can be masked by SPI (CR1: CANTO_IRQ_EN).
  – Wake-up from V1_Standby mode by any wake-up source

NINT is pulled low for t = $t_{interrupt}$

In case of increasing V1 load current during V1_Standby mode ($I_{V1} > I_{cmp\_ris}$), the device remains in standby mode and the watchdog starts with a Long Open Window. No Interrupt signal is generated.

4.3.6 CAN wake-up signalization

Table 61. CAN wake-up signalization

Operating mode	Event	Mode transition	Status flag	Interrupt pin
Active	WUP(1)	Transition to TRX_Ready	WUP(1)	RxD_C
	CAN Timeout	Transition to TRX_Sleep	CANTO	*RxD_C*(2)
	WUP(3)	Transition into TRX_Bias	WUP	*RxD_C* and *NINT*
V1_Standby	WUP(1)	Transition into Active mode; TRX_Ready	WAKE_CAN WUP(1)	*RxD_C* and *NINT*
	CAN Timeout	Transition to TRX_Sleep	CANTO	*RxD_C* and *NINT* (2)
	WUP(3)	Transition into TRX_Bias	WUP	*RxD_C* and *NINT*
VBAT_Standby	WUP(1)	Transition into Active mode; TRX_Ready	WAKE_CAN WUP(1)	none
	CAN Timeout	Transition to TRX_Sleep	CANTO	

1. PNW_EN = 0:
   - wake-up according ISO 11898-5:2007 (on WUP)
   - Flags: WUP (device in all modes), WAKE_CAN (device wake up by CAN from Standby modes)
2. Interrupt can be disabled by SPI (CANTO_IRQ_EN).
3. PWN_EN = 1 (Pretended Networking mode)
   - no wake-up
   - after reception of a wake-up patter (WUP) the transceiver enters TRX Bias mode
   - Flags: WUP

Note: See also Figure 30: CAN transceiver state diagram.

4.3.7 VBAT_Standby mode

The transition from Active mode to VBAT_Standby mode is initiated by an SPI command. In VBAT_Standby mode, the voltage regulators V1 and V2 (depending on configuration in CR 1), the power outputs (except OUT15 (d)) as well as LIN and CAN transmitters are switched off.

An NReset pulse is generated upon wake-up from VBAT_Standby mode.

4.4 Wake up from Standby Modes

A wake-up from standby mode will switch the device to active mode. This can be initiated by one or more of the following events:

d. This exception applies only if OUT15 is not driven with an internally generated PWM signal

Table 62. Wake-up events description

Wake up source	Description
LIN bus activity	Can be disabled by SPI
CAN bus activity	Can be disabled by SPI
Level change of WU	Can be configured or disabled by SPI
$I_{V1} > I_{cmp\_ris}$	Device remains in V1_Standby mode, but watchdog is enabled (If I_{CMP} = 0). No interrupt is generated.
Timer Interrupt / Wake up of µC by TIMER	Programmable by SPI: V1_Standby mode: configurable timer interrupt. NINT interrupt signal is generated VBAT_Standby mode: device wakes up after programmable timer expiration, V1 regulator is turned on and NReset signal is generated
SPI Access	Always active (except in VBAT_Standby *mode*) Wake up event: CSN is low and first rising edge on CLK
V_S Over Voltage	Only when Generator Mode is enabled (GENERATOR_MODE_EN=1 in CR22 0x16)

To prevent the system from a deadlock condition (no wake up from standby possible) a configuration where the wake up by LIN and HS CAN are both disabled is not allowed; in this case the SPI Error Bit *SPIE (Global Status Byte)* is set (see Note 1 in *Figure 62*).

4.4.1 Wake up inputs

The WU input can be configured as wake-up source. The wake-up input is sensitive to any level transition (positive and negative edge) and can be configured for static or cyclic monitoring of the input voltage level.

For static contact monitoring, a filter time of t_{WU_stat} is implemented. The filter is started when the input voltage passes the specified threshold V_{WU_THP} or V_{WU_THN}.

Cyclic contact monitoring allows periodical activation of the wake-up input to read the status of the external contact. The periodical activation can be configured to Timer 1 or Timer 2. The input signal is filtered with a filter time of t_{WU_CYC} after a delay (80% of the configured Timer on-time). A Wake-up will be processed if the status has changed versus the previous cycle. The buffered output OUT15 can be used to supply the external contacts with the timer setting according to the cyclic monitoring of the wake-up input.

In standby modes, the input WU is configurable with an internal pull-up or pull-down current source according to the setup of the external contact. In Active mode the inputs have an internal pull down resistor (R_{WU_act}) and the input status can be read by SPI. Static sense should be configured before the read operation is started in order to reflect the actual input level.

4.5 Functional Overview (truth table)

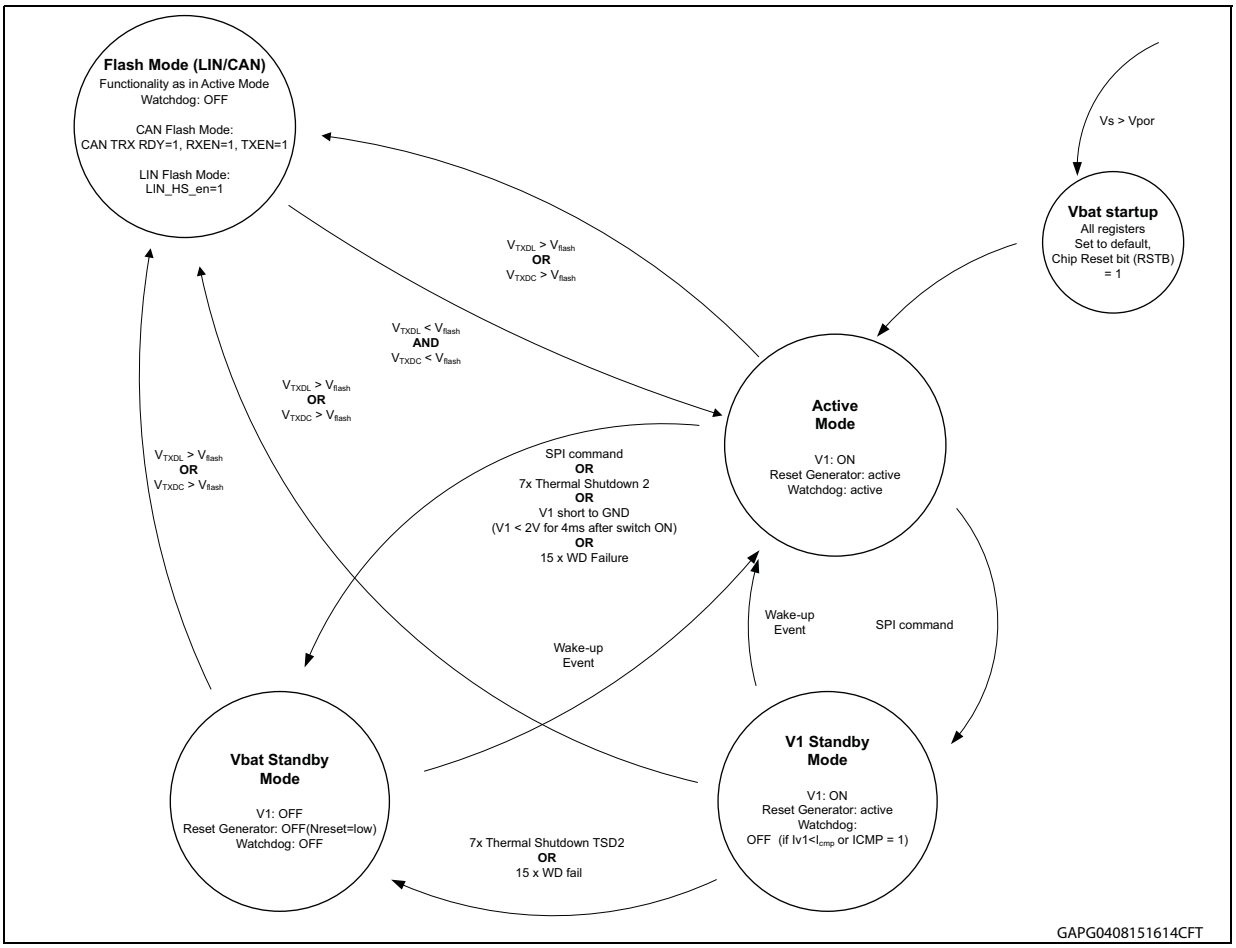
Table 63. Status of different functions/features vs operating modes

Function	Comments	Operating modes		
		Active mode	V1_Standby static mode (cyclic sense)	VBAT_Standby static mode (cyclic sense)
Voltage regulator V1	V_{OUT} = 5 V	On	On(1)	Off
Voltage tracker V2	V_{OUT} = 5 V	On/ Off(2)	On(2) / Off	On(2) / Off
Reset generator		On	On	Off
Window watchdog	V_1 monitor	On	Off (on if $I_{V1} > I_{CMP}$ and $I_{CMP} = 0$)	Off
Wake up		Off	Active(3)	Active(3)
OUT15 HS cyclic supply	Oscillator time base	On / Off	On(2) / Off	On(2) / Off
LIN	LIN 2.2a	On	Off(4)	Off(4)
HS_CAN		On / Off(5)	Off(4)	Off(4)
Oscillator OSC1	2 MHz	On	On/Off(6)	On/Off(6)
Oscillator OSC2	32 MHz	ON	Off	Off
$V_{SREG-Monitor}$		On	(7)	(7)
$V_{S-Monitor}$		On	Off	Off
H Bridge Gate Driver, EC control, bridge drivers, heater driver, all high-side drivers (except OUT15) supplied by V_S		On/ Off(2)	Off(8)	Off
Fail-safe low-side switches		On/ Off(9)	On	On
Short circuit protection for fail-safe low-side switches (in case LS is switched on)		On	On	On
OUT15 (P-channel HS) supplied by V_{SREG}		On/ Off(2)	On/ Off(2)(9)	On/ Off(2)(9)
Charge pump		On	Off	Off
ADC (SPI read out and V_{SREG} early warning interrupt)		On	Off	Off
Thermal shutdown TSD2		On	On	Off
Thermal shutdown TSD1x for OUT15 (P-channel HS)		On	On/ Off(2)	On/ Off(2)

1. Supply the processor in low current mode.
2. According to SPI setting and DIR.
3. Unless disabled by SPI.
4. The bus state is internally stored when going to standby mode. A change of bus state will lead to a wake-up after exceeding of internal filter time (if wake-up by LIN or CAN is not disabled by SPI).

5. After power-on, the HS CAN transceiver is in CAN_TRX_SLEEP mode. It is activated by SPI command (CAN_GO_TRX_RDY= 1).
6. ON, if cyclic sense is enabled or during wake-up request.
7. Cyclic activation = pulsed ON during cyclic sense.
8. In V1_Standby and VBAT_Standby modes OUT15 is ON only if it is not driven with an internally generated PWM signal.
9. ON in Fail-Safe mode; if standby mode is entered with active Fail-safe mode the output remains ON in standby mode.

Figure 22. Main operating modes



4.6 Configurable Window Watchdog

During normal operation, the watchdog monitors the microcontroller within a programmable trigger cycle.

After power-on or standby mode, the watchdog is started with a timeout (Long Open Window t_{LW}). The timeout allows the microcontroller to run its own setup and then to start the window watchdog by setting TRIG (CR1, Config Reg[e]) =1. Subsequently, the microcontroller has to

e. TRIG bits in CR1 and Config Reg are mirrored; either can be used for triggering the watchdog.

serve the watchdog by alternating the watchdog trigger bit TRIG (CR1, Config Reg[e]) within the safe trigger area T_{SWX}.

The trigger time is configurable by SPI. A correct watchdog trigger signal will immediately start the next cycle. After 8 watchdog failures in sequence, the V1 regulator is switched off for t_{V1OFF}. After 7 additional watchdog failures the V1 regulator is turned off permanently and the device goes into Forced VBAT_Standby mode. The status bit FORCED_SLEEP_WD (SR 1) is set. A wake-up is possible by any activated wake-up source.

After wake-up from Forced VBAT_Standby mode and the watchdog trigger still fails, the device enters Forced VBAT_Standby mode again after one Long Open Window.

This actually produces an additional watchdog failure but the watchdog fail counter will remain at maximum value of 15 failures.

This sequence is repeated until a valid watchdog trigger event is performed by writing TRIG = 1. In case of a Watchdog failure, the power outputs and V2 are switched off and the status bit WDFAIL (SR1) is set to 1. A reset pulse is generated at NReset output and the device enters Fail-safe mode. Control registers are set to their Fail Safe values and the Fail-safe low-side switches are turned on. Please refer to *Section 4.7: Fail Safe Mode* for more details.

The following diagrams illustrate the Watchdog behavior of the devices. The diagrams are split into 3 parts. The first diagram shows the functional behavior of the watchdog without any error. The second diagram covers the behavior covering all the error conditions, which can affect the watchdog behavior. *Figure 25: Watchdog in Flash mode* shows the transition in and out of Flash modes. Watchdog in normal operating mode (no errors)*Figure 23: Watchdog in normal operating mode (no errors)*, *Figure 24: Watchdog with error conditions* and *Figure 25: Watchdog in Flash mode* can be overlapped to get all the possible state transitions under all circumstances. For a better readability, they were split in normal operating, operating with errors and Flash mode.

Figure 23. Watchdog in normal operating mode (no errors)

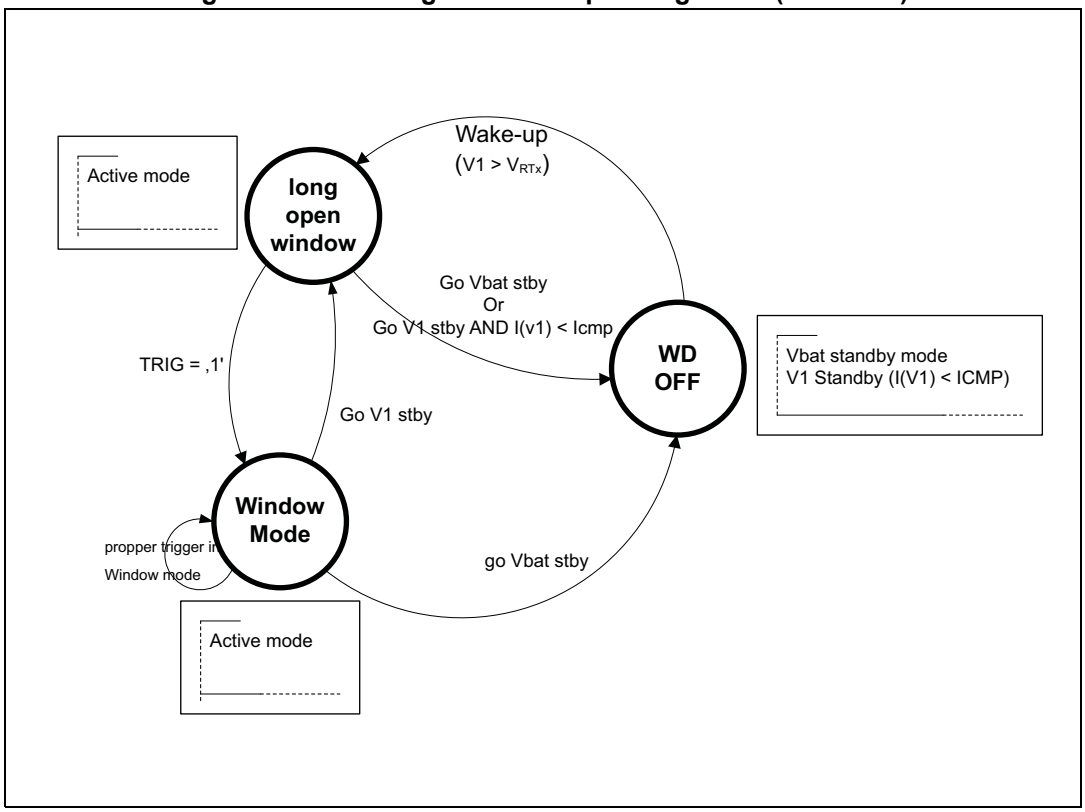


Figure 24. Watchdog with error conditions

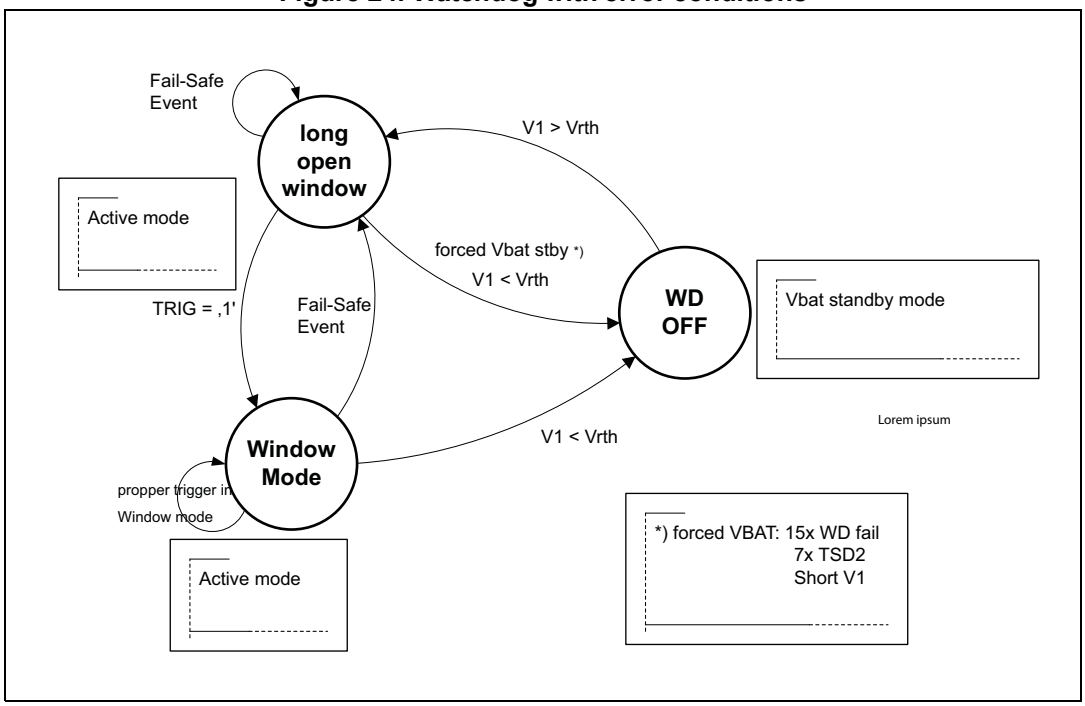
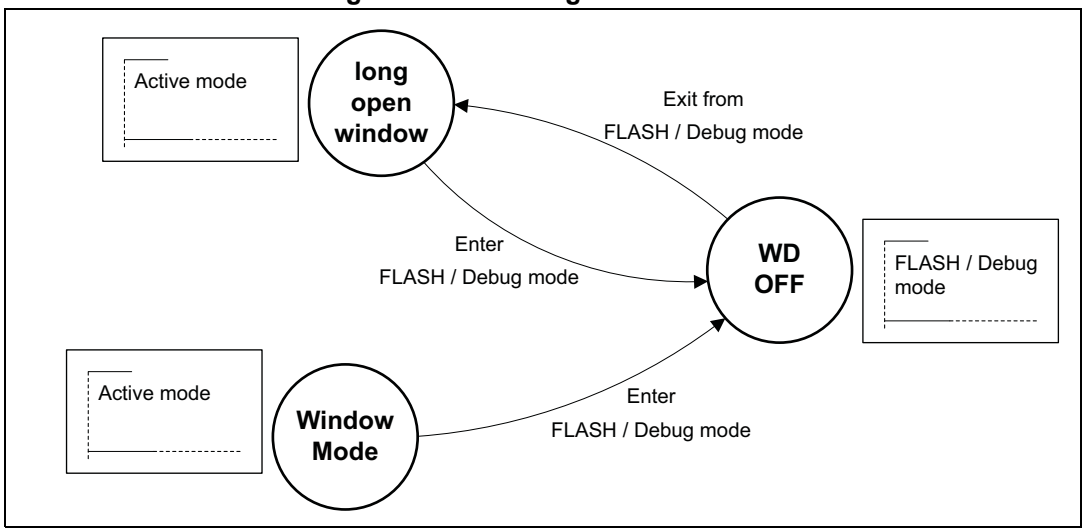


Figure 25. Watchdog in Flash mode



Note: Whenever the device is operated without servicing the mandatory watchdog trigger events, a sequence of 15 consecutive reset events is performed and the device enters the Forced VBAT_Standby mode with bit FORCED_SLEEP_WD in SR1 set. If the device is woken up after such a forced VBAT_Standby condition and the watchdog is still not serviced, the device, after one long open watchdog window will re-enter the same Forced VBAT_Standby mode until the next wake up event. In this case, an additional watchdog failure is generated, but the fail counter is not cleared, keeping the maximum number of 15 failures. This sequence is repeated until a valid watchdog trigger event is performed by writing TRIG = 1.

4.6.1 Change Watchdog timing

The watchdog trigger time is configured by setting WD_TIME_x (CR 2). Writing to these bits is possible only using the first SPI command after setting WD_CONFIG_EN = 1 (Config Reg). The WD_CONFIG_EN bit is reset to 0 automatically with the next SPI command.

4.7 Fail Safe Mode

4.7.1 Temporary Failures

The devices enter Fail-safe mode in case of:

- Watchdog failure
- V1 failure (V1 < $V_{RTxfalling}$ for t > t_{V1FS})
- Thermal Shutdown TSD2

The Fail Safe functionality is also available in V1_Standby mode. During V1_Standby mode the Fail Safe mode is entered in the following cases:

- V1 failure (V1 < $V_{RTxfalling}$ for t > t_{V1FS})
- Watchdog failure (if watchdog still running due to I_{V1} > I_{cmp_fal})
- Thermal Shutdown TSD2

In Fail Safe mode the devices return to a fail safe state. The Fail Safe condition is indicated to the system in the Global Status Byte. The conditions during Fail Safe mode are:

- All outputs beside LSA_FSO and LSB_FSO are turned off
- All Control Registers are set to fail safe default values except the GEN_MODE_EN
- Write operations to Control Registers are blocked until the Fail Safe condition is cleared. The following bits are not WRITE protected:
  - TRIG (CR1<bit 0>, Config Register <bit 0>): watchdog trigger bit
  - V2_x (CR1<bit 4:5>): Voltage Regulator V2 control
  - CAN_GO_TRX_RDY (CR1<bit 8>): activation of CAN bus biasing
  - CR2 (bit <8:23>): Timer1 and Timer2 settings
  - OUT15_x (CR6<bit 8:11>): OUT15 configuration
  - PWMx_freq_y (CR12): PWM frequency configuration
  - PWMx_DC_y (CR13 – CR16): PWM duty cycle configuration
- LIN and SPI remain on (transmitters are deactivated in case of thermal shutdown TSD1 (TSD1 cluster 5 or 6 in cluster mode)
- Corresponding Failure Bits in Status Registers are set
- FS Bit (Global Status Byte) is set
- LSA_FSO and LSB_FSO will be turned on
- Charge pump is switched off

If the Fail Safe mode was entered it keeps active until the Fail safe condition is removed and the Fail Safe was read by SPI. Depending on the root cause of the Fail Safe operation, the actions to exit Fail safe mode are shown in the following table.

Table 64. Temporary failures description

Failure source	Failure condition	Diagnosis	Exit from Fail-safe mode
Microcontroller (oscillator)	Watchdog early write failure or expired window	FS (Global Status Byte) =1; WDFAIL (SR 1) =1; WDFAIL_CNT_x (SR 1) = n+1	TRIG (CR 1) = 1 during long open window Read&Clear SR1
V1	Undervoltage	FS (Global Status Byte) = 1; V1UV (SR 1) = 1; V1fail (SR 2) = 1(1)	V1 >$V_{RTrising}$; Read&Clear *SR1*
Temperature	$T_j > T_{SD2}$	FS (Global Status Byte) = 1; TW (SR 2) = 1; TSD1 (SR 1) =1; TSD2 (SR 1) =1	$T_j < T_{SD2}$; Read&Clear *SR1*

1. If V1 < $V1_{fail}$ (for t > t_{V1fail}). The Fail-safe Bit is located in the Global Status Register.

4.7.2 Non-recoverable failures – forced VBAT_Standby mode

If the Fail-safe condition persists and all attempts to return to normal system operation fail, the devices enter the forced VBAT_Standby mode in order to prevent damage to the system. The forced VBAT_Standby mode can be terminated by any wake-up source (HS-CAN as well as LIN and WU pin). The root cause of the forced VBAT_Standby mode is indicated in the SPI Status Registers. In forced VBAT_standby mode and with Fail Safe conditions still present at wake-up, the Fails safe low side outputs LSy_FSO (y = A, B) are switched OFF for 25 µs after the wake up event.

In Forced VBAT_Standby mode, all Control Registers are set to power-on default values.

The Forced VBAT_Standby mode is entered in case of:

- Multiple watchdog failures: FORCED_SLEEP_WD (SR 1) = 1 (15 x watchdog failure)
- Multiple thermal shutdown 2: FORCED_SLEEP_TSD2/V1SC (SR 1) = 1 (7 x TSD2)
- V1 short at turn-on ($V1 < V1_{fail}$ for $t > t_{V1short}$):
  FORCED_SLEEP_TSD2/V1SC (SR 1) = 1
- SGND Loss: SGND_LOSS (SR 1) = 1

Table 65. Non-recoverable failure

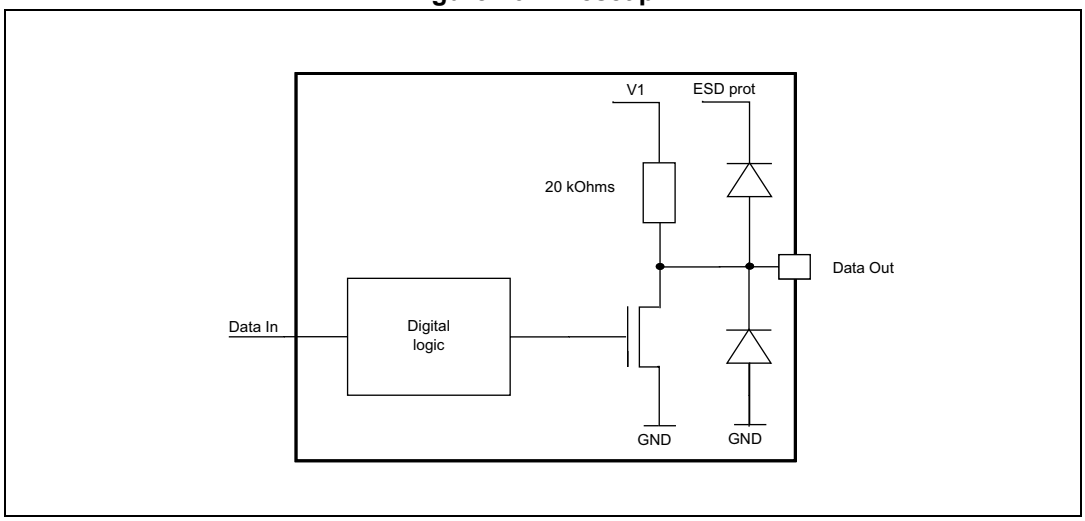
Failure source	Failure condition	Diagnosis	Exit from Fail-safe mode
Microcontroller (Oscillator)	15 consecutive Watchdog Failures	FS (Global Status Byte) = 1; WDFAIL (SR 1) = 1; FORCED_SLEEP_WD (SR 1) = 1	Wake-up; TRIG (CR 1) = 1 during long open window; Read&Clear SR1
V1	Short at turn-on	FS (Global Status Byte) = 1; FORCED_SLEEP_TSD2/V1SC (SR 1) = 1	Wake-up; Read&Clear SR1
Temperature	7 times TSD2	FS (Global Status Byte) =1; TW (SR 2) = 1; TSD1 (SR 1) = 1; TSD2 (SR 1) = 1; FORCED_SLEEP_TSD2/V1SC (SR 1) = 1	Wake-up; Read&Clear SR1
SGND Loss	Ground Loss at pin SGND	FS (Global Status Byte) = 1; SGND_LOSS (SR 1) = 1	Wake-up; Read&Clear *SR1*

In Forced VBAT_Standby mode:

- when Vs OV is detected, in case of non recoverable conditions (WD, TSD2, V1 short or SGND loss), the device will stay in Temporary Fail Safe state;
- during this state (VSOV + failure conditions), diagnosis will be set (FS, WDFAIL or TW, TSD1, TSD2 or FORCED_SLEEP_TSD2/VS1SC or SGND_LOSS) even if the device is not in Forced VBAT_Standby mode;
- as soon Vs OV disappears, the device will enter in Forced VBAT_Standby mode.

4.8 Reset output (NReset)

Figure 26. NReset pin



If V1 is turned on and the voltage exceeds the V1 reset threshold, the reset output *NReset* is pulled up to V1 by an internal pull-up resistor after a reset delay time (t_{V1R}). This is necessary for a defined start of the microcontroller when the application is switched on.

Since the NReset output is realized as an open drain output it is also possible to connect that, instead of the 5V_1, to an external voltage source (it has to be compatible with a 5V rail). As soon as the NReset is released by the devices the watchdog starts with a long open window.

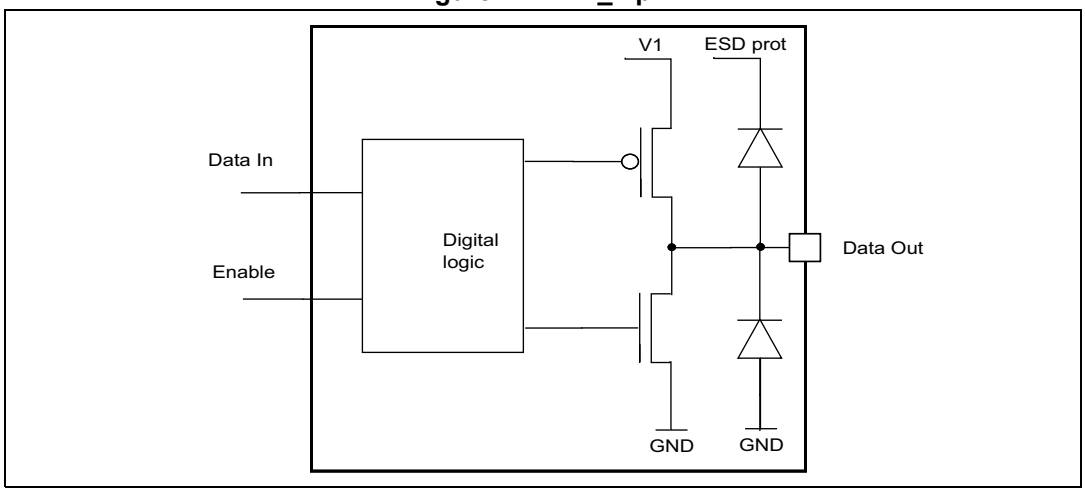
A reset pulse is generated in case of:

- V1 drops below $V_{RTxfalling}$ (configurable by SPI) for t > t_{UV1}
- Watchdog failure

After turn ON of the V1 regulator (VSREG Power-on or wake-up from VBAT_Standby mode), NReset is kept low for tv1r in order to keep the uC in reset until supply voltage is stable.

4.9 LIN Bus Interface

Figure 27. RxD_L pin



4.9.1 Features

- LIN 2.2a compliant (SAEJ2602 compatible) transceiver
- LIN Cell has been designed according to “Hardware requirements for transceivers (version 1.3)”
- Bit rate up to 20 kbit/s
- Designed according to SAE J2962-1 (July 2019)
- Dedicated LIN Flash mode with bit rate up to 100 kbit/s
- GND disconnection fail safe at module level
- Off mode: does not disturb network
- GND shift operation at system level
- Microcontroller Interface with CMOS-compatible I/O pins
- Internal pull-up resistor
- Receive-only mode
- ESD and transient immunity according to ISO7637 and EN / IEC61000-4-2
- Matched output slopes and propagation delay
- Wake-up behavior according to LIN2.2a and Hardware Requirements for LIN, CAN and Flexray Interfaces (version 1.3)

At $V_{SREG} > V_{POR}$ (i.e. V_{SREG} power-on reset threshold), the LIN transceiver is enabled. The LIN transmitter is disabled in case of the following errors:

- Dominant TxD_L time out
- LIN permanent recessive
- Thermal shutdown 1
- V_{SREG} overvoltage/ undervoltage

The LIN receiver is not disabled in case of any failure condition.

The default bit rate of the transceiver allows communication up to 20 kbit/s. To enable fast flashing via the LIN bus, the transceiver can be operated in high speed mode by setting bit LIN_HS_EN (Config Reg) = 1. This feature is enabled automatically in LIN Flash mode.

4.9.2 Error Handling

The devices LIN transceiver provides the following 3 error handling features.

Dominant TxD_L time out

If TXD_L is in dominant state (low) for t > $t_{dom(TXDL)}$ the transmitter will be disabled, the status bit LIN_TXD_DOM (SR 2) will be set.

The transmitter remains disabled until the status bit is cleared.

The TxD dominant timeout detection can be disabled via SPI (LIN_TXD_TOUT_EN = 0).

Permanent recessive

If TXD_L changes to dominant (low) state but RXD_L signal does not follow within t < t_{LIN} the transmitter will be disabled, the status bit LIN_PERM_REC (SR 2) will be set.

The transmitter remains disabled until the status bit is cleared.

Permanent dominant

If the bus state is dominant (low) for t > $t_{dom(bus)}$ a bus permanent dominant failure will be detected. The status bit LIN_PERM_DOM (SR 2) will be set.

The transmitter will not be disabled.

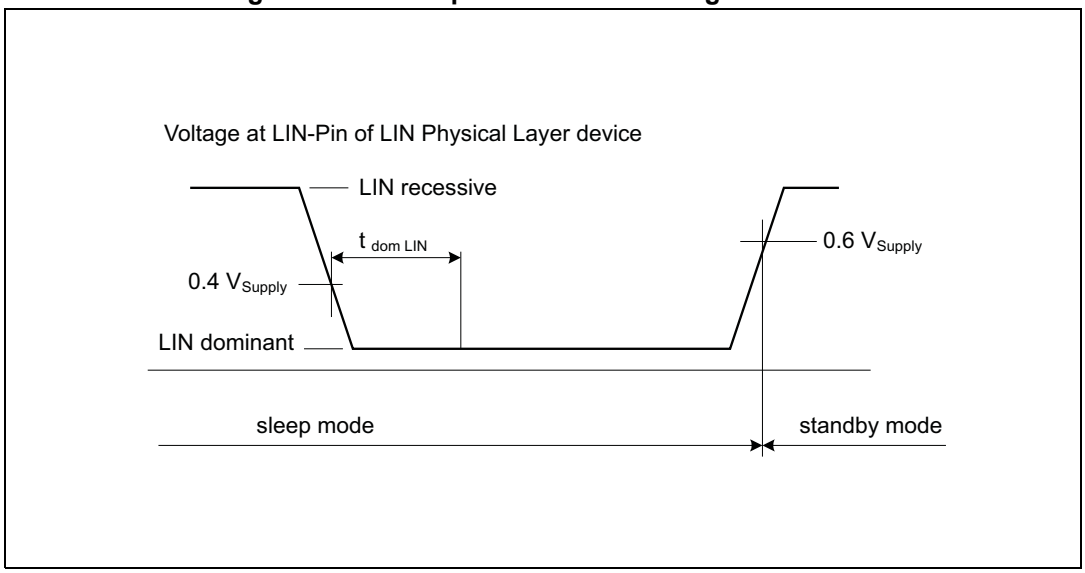
4.9.3 Wake up from Standby Modes

In low power modes (V1_Standby mode and VBAT_Standby mode) the devices can receive two types of wake up signals from the LIN bus (configurable by SPI bit LIN_WU_CONFIG (Config Reg)):

- Recessive-Dominant-recessive pattern with t > t_{dom_LIN} (default, according to LIN 2.2a)
- State Change recessive-to-dominant or dominant-to-recessive (according to LIN 2.1)

Pattern Wake-up (default)

Figure 28. Wake-up behavior according to LIN 2.2a



Status change wake-up - Recessive-to-dominant

Normal wake-up can occur when the LIN transceiver was set in standby mode while LIN was in recessive (high) state. A dominant level at LIN for t > t_{LINBUS}, will switch the devices in Active mode.

Status change wake-up - Dominant-to-recessive

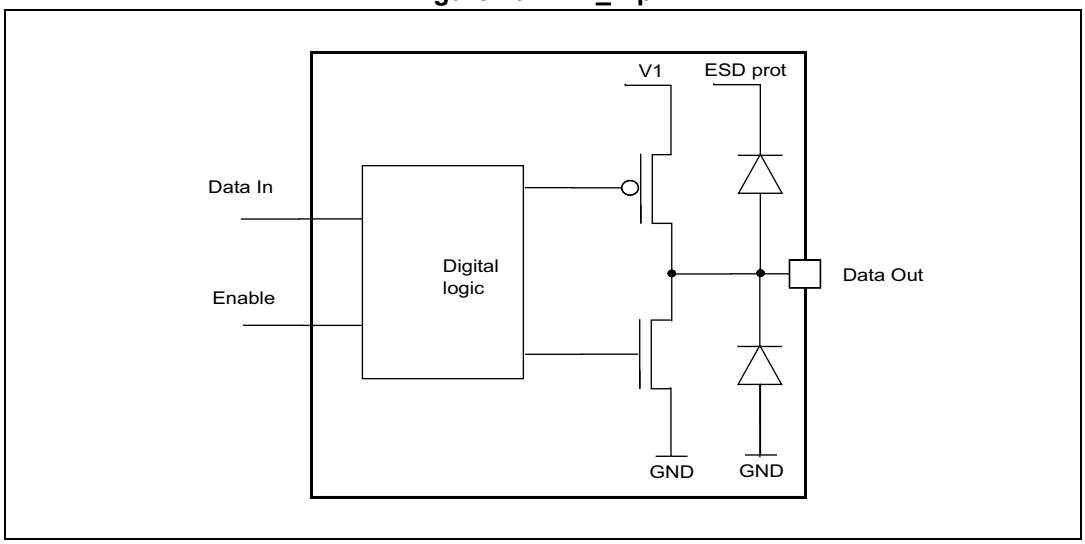
If the LIN transceiver was set in standby mode while LIN was in dominant (low) state, recessive level at LIN for t > t_{LINBUS}, will switch the devices in Active mode.

4.9.4 Receive-only mode

The LIN transmitter can be disabled in Active mode by setting the bit LIN_REC_ONLY (CR2). In this mode it is possible to listen to the bus but not sending to it.

4.10 High-speed CAN bus transceiver

Figure 29. RxD_C pin

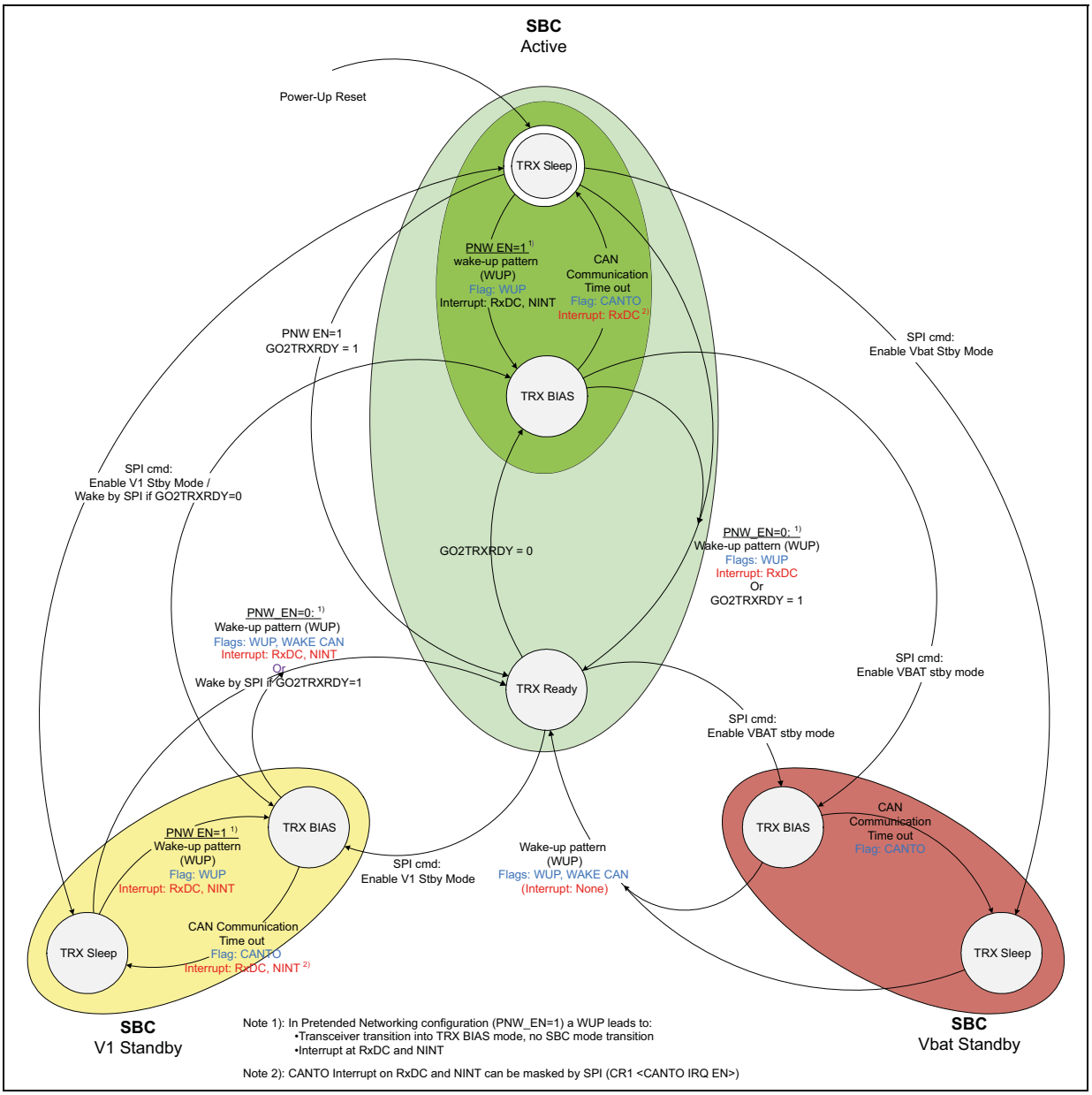


4.10.1 Features

- ISO 11898-2:2003 and ISO 11898-5:2007 compliant
- CAN High Speed Transceiver Conformance Test according to «Interoperability test specification for high-speed CAN transceiver or equivalent devices IOPT.CAN v02d00»
- HS-CAN cell has been designed according to “Hardware requirements for transceivers (version 1.3)”
- Supports pretended networking
- Listen mode (transmitter disabled)
- Enhanced Voltage Biasing according to ISO 11898-6:2013
- SAE J2284 compliant
- Bit rate up to 1Mbit/s
- Designed according to SAE J2962-2 (July 2019)
- Function range from -27 V to +40 V DC at CAN pins.
- GND disconnection fail safe at module level.
- GND shift operation at system level.
- Microcontroller Interface with CMOS compatible I/O pins.
- ESD and transient immunity according to ISO7637 and EN / IEC61000-4-2
- Matched output slopes and propagation delay

4.10.2 CAN Transceiver operating modes

Figure 30. CAN transceiver state diagram



TRX Ready State

In this state the bus-biasing is on.

The transmitter and receiver can be configured by SPI (RXEN, TXEN) as follows:

- TRX Standby (default): transmitter and receiver disabled
- TRX Listen: transmitter disabled, receiver enabled
- TRX Normal: transmitter enabled, receiver enabled

TRX BIAS State

In this transceiver state the bus biasing is on and the Automatic Voltage Biasing is active (i.e. transceiver enters TRX_Sleep at t > $t_{Silence}$ and turns off the biasing).

The CAN transmitter is disabled. The receiver can be configured by SPI (RXEN) as follows:

- TRX Standby (default): receiver disabled
- TRX Listen: receiver enabled

The CAN receiver is capable of detecting a wake-up pattern (WUP). In V1_Standby mode and Active mode, a wake-up is indicated to the micro-controller by an interrupt signal and the transceiver enters TRX_Ready State (receiver and transmitter according to setting of TXEN and RXEN). After serving the interrupt, the microcontroller can enable the receiver and transmitter by setting TXEN = 1 and RXEN = 1.

TRX SLEEP State

After Power-on the CAN transceiver enters TRX_Sleep state. In this state, the CAN transceiver is disabled and the biasing is turned off. Transmitter and receiver are disabled (TRX_Standby state). After the detection of CAN communication (WUP), an interrupt signal is generated and the transceiver enters TRX_Ready state (if PNWEN = 0) or TRX_BIAS state (if PNWEN = 1). Receiver and transmitter are configured according to setting of TXEN and RXEN.

TRX_Sleep state is entered automatically after a CAN communication timeout (see *Section 4.10.3: Automatic Voltage Biasing*).

4.10.3 Automatic Voltage Biasing

The Automatic Voltage Biasing is described in ISO 11898-6:2013. This feature is active in all transceiver low-power modes independent of the SBC operating modes.

If there has been no activity on the bus for longer than $t_{Silence}$, the bus lines are biased towards 0V via the receiver input resistors R_{in}. If wake-up activity on the bus lines is detected (Wake-up pattern, WUP), the bus lines are biased to $V_{CANHrec}$ respectively $V_{CANLrec}$ via the internal receiver input resistors R_{in}. The biasing is activated not later than t_{Bias}.

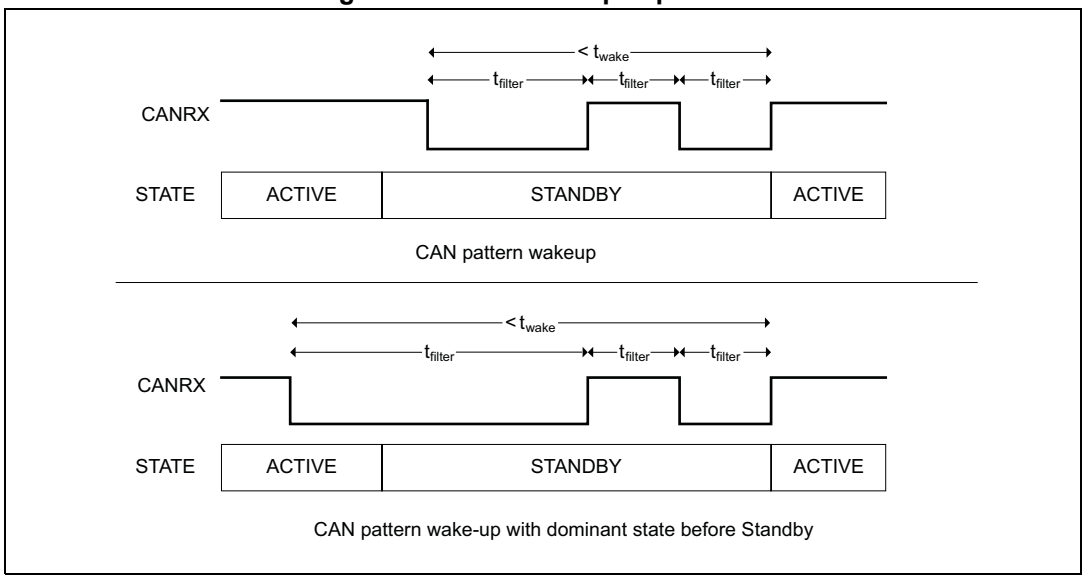
4.10.4 Wake up by CAN

The device supports only the wake-up by any bus activity according to ISO 11898-2:2003/-5:2007.

The default setting for the wake up behavior after Power-on reset is the wake-up by regular communication on the CAN bus according to ISO 11898-5:2007. When the CAN transceiver is in a low power mode (TRX_BIAS or TRX_Sleep) the device can be woken up by sending 2 consecutive dominant bits separated by a recessive bit.

A wake-up can be detected if the CAN transceiver was set in standby mode while the CAN bus was in recessive (high) state or dominant (low) state (see *Figure 31*).

Figure 31. CAN wake up capabilities



For details, see *Figure 30*.

4.10.5 CAN looping

If CAN_LOOP_EN (CR 2) is set the TxD_C input is mapped directly to the RxD_C pin. This mode can be used in combination with the CAN Receive-only mode, to run diagnosis for the CAN protocol handler of the microcontroller.

4.10.6 Pretended Networking

To support pretended networking concepts, the devices can be configured as follows:

- V1_Standby mode or Active mode (if watchdog is required)
- Pretended Networking enabled (PNW_EN (CR 2) = 1)

In this configuration, the microcontroller is supplied by V1 in low current mode. The CAN Automatic Voltage Biasing is active. Upon incoming CAN messages, the biasing is turned on (TRX_BIAS State) and an interrupt is generated. If the device is in V1_Standby mode it remains in this mode.

The incoming CAN frames are passed to the microcontroller via the RxD_C signal line for decoding.

4.10.7 CAN Error Handling

The devices provide the following four error handling features. After Power-on Reset (V_S > V_{POR}) the CAN transceiver is disabled. The transceiver is enabled by setting CAN_GO_TRX_RDY (CR 1) = 1. The CAN transmitter will be disabled automatically in case of the following errors:

- Dominant TxD_C time out
- CAN permanent recessive
- RxD_C permanent recessive
- Thermal Shutdown 1

The CAN receiver is not disabled in case of any failure condition.

Dominant TxD_C time out

If TXD_C is in dominant state (low) for t > $t_{dom\ (TxDC)}$ the transmitter will be disabled, CAN_TXD_DOM (SR 2) will be latched and can be read and optionally cleared by SPI. The transmitter remains disabled until the status register is cleared.

CAN Permanent Recessive

If TXD_C changes to dominant (low) state but CAN bus does not follow for 4 times, the transmitter will be disabled, CAN_PERM_REC (SR 2) will be latched and can be read and optionally cleared by SPI. The transmitter remains disabled until the status register is cleared.

CAN Permanent Dominant

If the bus state is dominant (low) for t > t_{CAN} a permanent dominant status will be detected. CAN_PERM_DOM (SR 2) will be latched and can be read and optionally cleared by SPI. The transmitter will not be disabled.

RxD_C Permanent Recessive

If RxD_C pin is clamped to recessive (high) state, the controller is not able to recognize a bus dominant state and could start messages at any time, which results in disturbing the overall bus communication. Therefore, if RXD_C does not follow TXD_C for 4 times the transmitter will be disabled. CAN_RXD_REC (SR 2) will be latched and can be read and optionally cleared by SPI. The transmitter remains disabled until the status register is cleared.

4.11 Serial Peripheral Interface (ST SPI Standard)

A 32-bit SPI is used for bi-directional communication with the microcontroller.

The SPI is driven by a microcontroller with its SPI peripheral running in the following mode: CPOL = 0 and CPHA = 0. For this mode input data is sampled by the low to high transition of the clock CLK, and output data is changed from the high to low transition of CLK.

This device is not limited to microcontroller with a built-in SPI. Only three CMOS-compatible output pins and one input pin are needed to communicate with the device. A fault condition can be detected by setting CSN to low. If CSN = 0, the DO-Pin reflects the global error flag (fault condition) of the device.

- Chip Select Not (CSN)
  The input Pin is used to select the serial interface of this device. When CSN is high, the output Pin (DO) is in high impedance state. A low signal activates the output driver and a serial communication can be started.
  The state during CSN = 0 is called a communication frame.
  If CSN = low for t > $t_{CSNfail}$ the DO output is switched to high impedance in order to not block the signal line for other SPI nodes.
- Serial Data In (DI)
  The input Pin is used to transfer data serial into the device. The data applied to the DI is sampled at the rising edge of the CLK signal and shifted into an internal 32-bit shift register. At the rising edge of the CSN signal the content of the shift register is transferred to Data Input Register. The writing to the selected Data Input Register is only

enabled if exactly 32 bits are transmitted within one communication frame (i.e. CSNlow). If more or less clock pulses are counted within one frame the complete frame is ignored. This safety function is implemented to avoid an activation of the output stages by a wrong communication frame.

Note: Due to this safety functionality a daisy chaining of SPI is not possible. Instead, a parallel operation of the SPI bus by controlling the CSN signal of the connected IC's is recommended.

- Serial Data Out (DO)
  The data output driver is activated by a logical low level at the CSN input and will go from high impedance to a low or high level depending on the global error flag (fault condition). The first rising edge of the CLK input after a high to low transition of the CSN Pin will transfer the content of the selected status register into the data out shift register. Each subsequent falling edge of the CLK will shift the next bit out.
- Serial Clock (CLK)
  The CLK input is used to synchronize the input and output serial bit streams. The data input (DI) is sampled at the rising edge of the CLK and the data output (DO) will change with the falling edge of the CLK signal. The SPI can be driven with a CLK Frequency up to 4 MHz.

4.12 Power Supply Fail

4.12.1 Vs supply failure

Vs overvoltage

If the supply voltages V_S reaches the overvoltage threshold V_{SOV}:

- LIN remains enabled
- CAN remains enabled
- OUT1 to OUT14 are turned off (default).

The shutdown of outputs may be disabled by SPI (VS_OV_SD_EN (CR 3) = 0)

- Charge pump is disabled (and is switched on automatically in case the supply voltage recovers to normal operating voltage)
- H-bridge gate driver and heater MOSFET gate driver are switched into sink condition
- ECV is switched in high impedance state and ECDR is discharged by $R_{ECDRDIS}$ (to ensure the gate of the external MOSFET is discharged => EC mode considered as off)
- Recovery of outputs after overvoltage condition is configurable by SPI:
  - VS_LOCK_EN (CR 3) = 1: outputs are off until Read&Clear VS_OV (SR 2).
  - VS_LOCK_EN (CR 3) = 0: outputs turned on automatically after V_S overvoltage condition has recovered.
- The overvoltage bit VS_OV (SR 2) is set and can be cleared with a ‘Read&Clear’ command. The overvoltage bit is reset automatically if VS_LOCK_EN (CR 3) = 0 and the overvoltage condition has recovered.

Vs undervoltage

If the supply voltage V_S drops below the under voltage threshold voltage (V_{SUV}):

- LIN remains enabled
- CAN remains enabled
- OUT1 to OUT14 are turned off (default).
  The shutdown of outputs may be disabled by SPI (VS_UV_SD_EN (CR 3) = 0)
- H-bridge drivers A and B are turned off (default). The shutdown of H-bridge drivers may be disabled by SPI (VS_UV_SD_EN (CR 3) = 0)
- Heater MOSFET gate driver is switched into sink condition
- ECV is switched in high impedance state and ECDR is discharged by $R_{ECDRDIS}$ (to ensure the gate of the external MOSFET is discharged => EC mode considered as off)
- Recovery of outputs and H-bridge drivers after undervoltage condition is configurable by SPI:
  - VS_LOCK_EN (CR 3) = 1: outputs and H-bridge drivers are off until Read&Clear VS_UV (SR 2).
  - VS_LOCK_EN (CR 3) = 0: outputs and H-bridge drivers turned on automatically after V_S undervoltage condition has recovered.
- The undervoltage bit VS_UV (SR 2) is set and can be cleared with a ‘Read&Clear’ command. The undervoltage bit is removed automatically if VS_LOCK_EN (CR 3) = 0 and the undervoltage condition has recovered.

4.12.2 Vsreg supply failure

Vsreg Overvoltage

If the supply voltages V_{SREG} reaches the overvoltage threshold V_{SREG_OV}:

- LIN transmitter is switched to high impedance
- CAN remains enabled
- OUT15 is turned off (default).

The shutdown of outputs may be disabled by SPI (VSREG_OV_SD_EN (CR 3) = 0)

- Recovery of outputs after overvoltage condition is configurable by SPI:
  - VSREG_LOCK_EN (CR 3) = 1: outputs are off until Read&Clear VSREG_OV (SR 2).
  - VSREG_LOCK_EN (CR 3) = 0: outputs turned on automatically after V_{SREG} overvoltage condition has recovered.
- The overvoltage bit VSREG_OV (SR 2) is set and can be cleared with a ‘Read&Clear’ command. The overvoltage bit is reset automatically if VSREG_LOCK_EN (CR 3) = 0 and the overvoltage condition has recovered.

Vsreg Undervoltage

If the supply voltage V_{SREG} drops below the under voltage threshold voltage (V_{SREG_UV}):

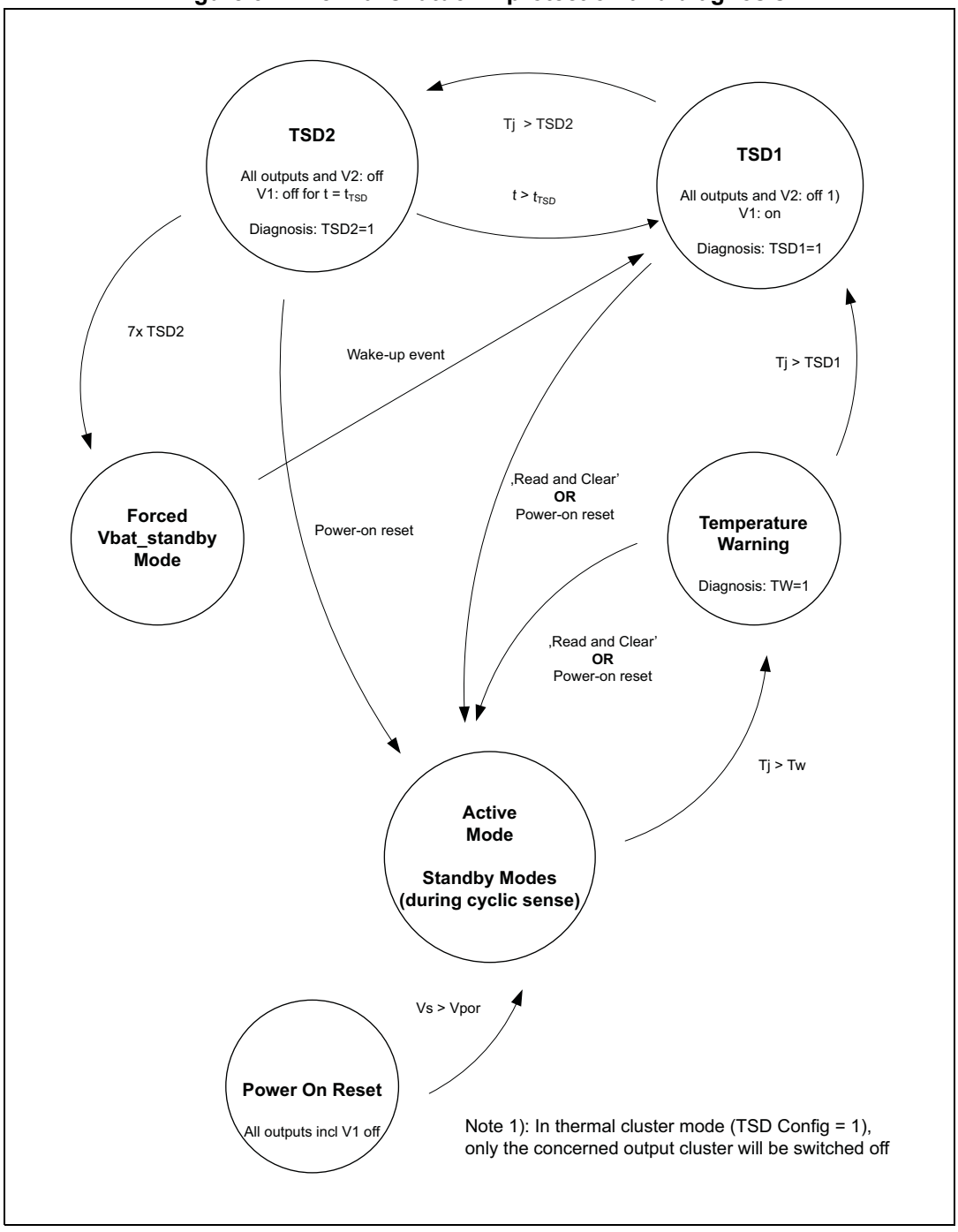
- LIN transmitter is switched to high impedance
- CAN remains enabled
- OUT15 is turned off (default).

The shutdown of outputs may be disabled by SPI (VSREG_UV_SD_EN (CR 3) = 0)

- Recovery of outputs after undervoltage condition is configurable by SPI:
  - VSREG_LOCK_EN (CR 3) = 1: outputs are off until Read&Clear VSREG_UV (SR 2).
  - VSREG_LOCK_EN (CR 3) = 0: Outputs turned on automatically after V_{SREG} undervoltage condition has recovered.
- The undervoltage bit VSREG_UV (SR 2) is set and can be cleared with a 'Read&Clear' command. The undervoltage bit is removed automatically if VSREG_LOCK_EN (CR 3) = 0 and the undervoltage condition has recovered.

4.13 Temperature warning and thermal shut-down

Figure 32. Thermal shutdown protection and diagnosis



Note: The Thermal State machine will recover the same state where it was before entering Standby mode. In case of a TSD2 it will enter TSD1 state.

4.14 Power Outputs OUT1…15

The component provides a total of 4 half bridges outputs OUT1, OUT2, OUT3 and OUT6 to drive motors and 7 stand alone high-side outputs OUT7, OUT8, OUT9, OUT10, OUT13, OUT14 and OUT15 to drive e.g. LED's, bulbs or to supply contacts. All high-side outputs beside OUT15 are supplied by the pin VS and OUT15 is supplied by the buffered supply VSREG. Beside OUT15 the high-side switches can be activated only in case of running charge pump.

OUT15 can be activated also in standby modes, except if OUT15 is driven by an internally generated PWM.

All high-side and low-side outputs switch off in case of:

- VS (VSREG) overvoltage and undervoltage (depending on configuration, see *Section 4.12.2: Vsreg supply failure*)
- Overcurrent (depending on configuration, auto recovery mode (see below)
- Overtemperature (TSD1x/ cluster or single mode)
- Fail safe event
- Loss of GND at SGND pin

In case of overcurrent or overtemperature (TSD1_CLx (SR 6)) condition, the drivers will switch off. The relative status bit will be latched and can be read and optionally cleared by SPI. The drivers remain off until the status is cleared. In case overvoltage/ undervoltage condition, the drivers will be switched off. The relative status bit will be latched and can be read and optionally cleared by SPI. If VSREG_LOCK_EN (CR 3) respectively VS_LOCK_EN (CR 3) are set, the drivers remain off until the status is cleared. If the VS_LOCK_EN or VSREG_LOCK_EN bit is set to 0, the drivers will switch on automatically if the error condition disappears. Undervoltage and overvoltage shutdown can be disabled by SPI. In case of open-load condition, the relative status register will be latched. The status can be read and optionally cleared by SPI. The high and low-side outputs are not switched off in case of open-load condition.

For OUT1, OUT2, OUT3 and OUT6, OUT7, OUT8 and OUT15 the auto recovery feature (OUTx_OCR (CR 7)) can be enabled. If these bits are set to 1 the driver will automatically restart from an overload condition. This overload recovery feature is intended for loads which have an initial current higher than the overcurrent limit of the output (e.g. Inrush current of cold light bulbs). The SPI bits OUTx_OCR_ALERT (SR4) indicate that the output reached auto-recovery condition.

Note: The maximum voltage and current applied to the High-side Outputs is specified in the 'Absolute Maximum Ratings'. Appropriate external protection may be required in order to respect these limits under application conditions.

Each of the 7 standalone high-side driver outputs from OUT7 to OUT15 can be driven with an internally generated PWM signal, an internal Timer or through the DIR signal.

Moreover, for OUT7, OUT8 and OUT9 high-side driving LEDs, it is also available the CCM (Constant Current Mode) feature, which is configurable by SPI (CR9) and conceived to provide a constant current to the related output (see more detail in *Section 4.21: Constant current mode*).

Table 66: Power output settings summarizes the possible configurations for the high-side outputs.

Table 66. Power output settings

OUTx_3	OUTx_2	OUTx_1	OUTx_0	Description
0	0	0	0	OFF
0	0	0	1	ON
0	0	1	0	Timer1 output is controlled by timer1; starting with ON phase after timer restart
0	0	1	1	Timer2 output is controlled by timer2; starting with ON phase after timer restart
0	1	0	0	PWM1
0	1	0	1	PWM2
0	1	1	0	PWM3
0	1	1	1	PWM4
1	0	0	0	PWM5
1	0	0	1	PWM6
1	0	1	0	PWM7
1	0	1	1	Not applicable
1	1	0	0	Not applicable
1	1	0	1	Not applicable
1	1	1	0	DIR
1	1	1	1	Not applicable

4.15 Auto-recovery alert and thermal expiration

The thermal expiration feature provides a robust protection against possible microcontroller malfunction, switching off a given channel if continuously driven in auto-recovery. If the temperature of the related cluster increases by more than 30 °C after reaching the auto-recovery time t_{AR}, the channel is switched off. The thermal expiration status bit OUTx_TH_EX [f] (SR 3) is set.

During auto-recovery condition, OUTx_OCR_ALERT[f] (SR 4) is set. The Alert bit indicates that an overload condition (load in-rush, short-circuit, etc) is present.

The thermal expiration feature can be activated only in combination with Over Current Recovery (or Auto-recovery) mode, by setting to 1 both the OUTx_OCR[f] (CR7) and the OUTx_OCR_THX_EN[f] (CR8) bits.

f. For x = 1, 2, 3, 6, 7, 8, 15.

Figure 33. Example of long auto-recovery on OUT7. Temperature acquisition starts after t_{AR}, thermal expiration occurs after Δ=30°

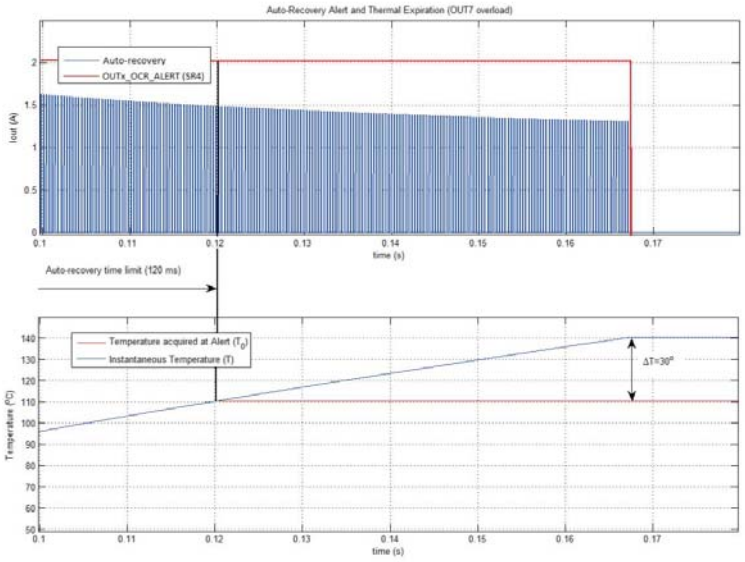
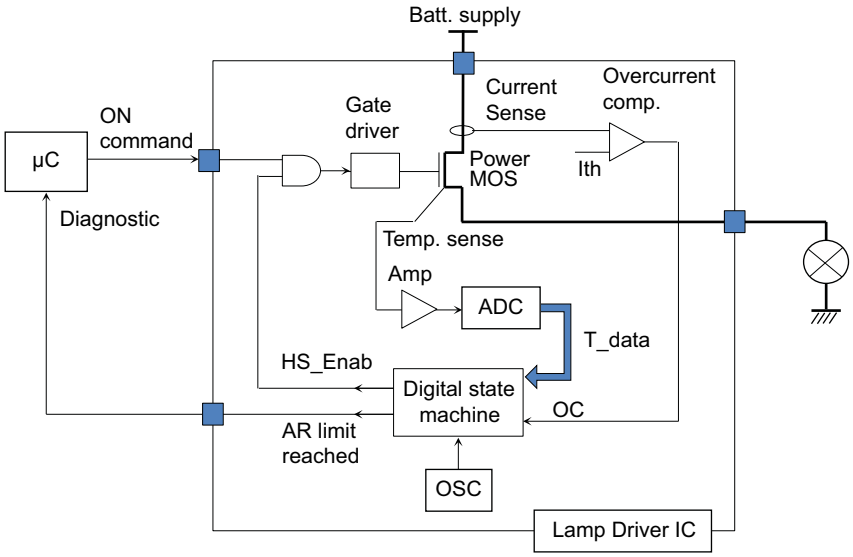


Figure 34. Block diagram of physical realization of AR alert and thermal expiration



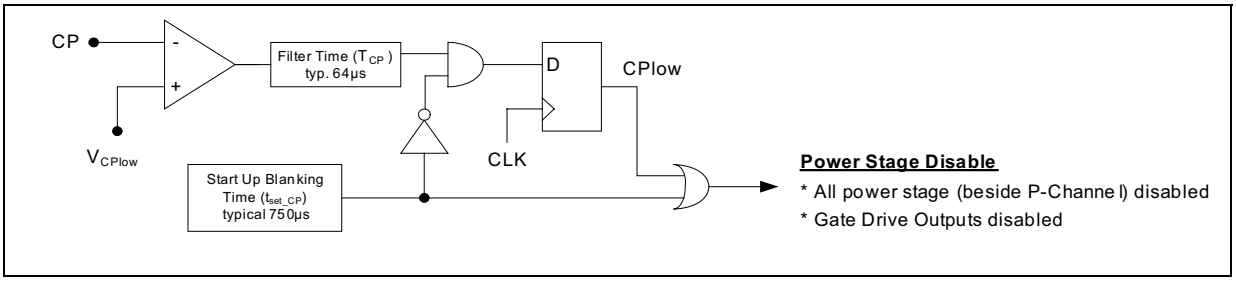
4.16 Charge Pump

The charge pump uses two external capacitors, which are switched with f_{CP}. The output of the charge pump has a current limitation. In standby mode and after a thermal shutdown has been triggered the charge pump is disabled. If the charge pump output voltage remains too low for longer than T_{CP}, the power-MOS outputs and the EC-control are switched off.

The H-bridge MOSFET gate drivers and the Heater MOSFET gate driver are switched to resistive low and CP_LOW (SR 2) is set. This bit has to be cleared to reactivate the drivers. If the bit CP_LOW_CONFIG (Configuration Register 0x3F) is set to '1', CP_LOW (SR2) behaves as a 'live' bit and the outputs are re-activated automatically upon recovery of the charge pump output voltage.

In case of reaching the overvoltage shutdown threshold V_{SOV} the charge pump is disabled and automatically restarted after V_S recovered to normal operating voltage.

Figure 35. Charge pump low filtering and start up implementation



4.17 Inductive Loads

Each of the half bridges is built by internally connected high-side and low-side power DMOS transistors. Due to the built-in reverse diodes of the output transistors, inductive loads can be driven at the outputs OUT1...OUT6 without external freewheeling diodes. The high-side drivers OUT7. OUT15 are intended to drive resistive loads only. Therefore only a limited energy (E < 1 mJ) can be dissipated by the internal ESD-diodes in freewheeling condition. For inductive loads (L > 100 µH) an external freewheeling diode connected between GND and the corresponding output is required. The low-side driver at ECV does not have a freewheel diode built into the device.

4.18 Open-load detection

The open-load detection monitors the load current in each activated output stage. If the load current is below the open-load detection threshold for t > t_{OL_OUT} the corresponding open-load bit OUTx_OL_STAT (SR 5) is set in the status register.

4.19 Overcurrent Management: Recovery or Latch

All the embedded outputs of the L99DZ200G, from OUT1 to OUT15, come with the Over Current Detection (Latch); this feature is enabled by default and in case of overcurrent, the corresponding driver switches OFF to reduce the power dissipation and to protect the integrated circuit.

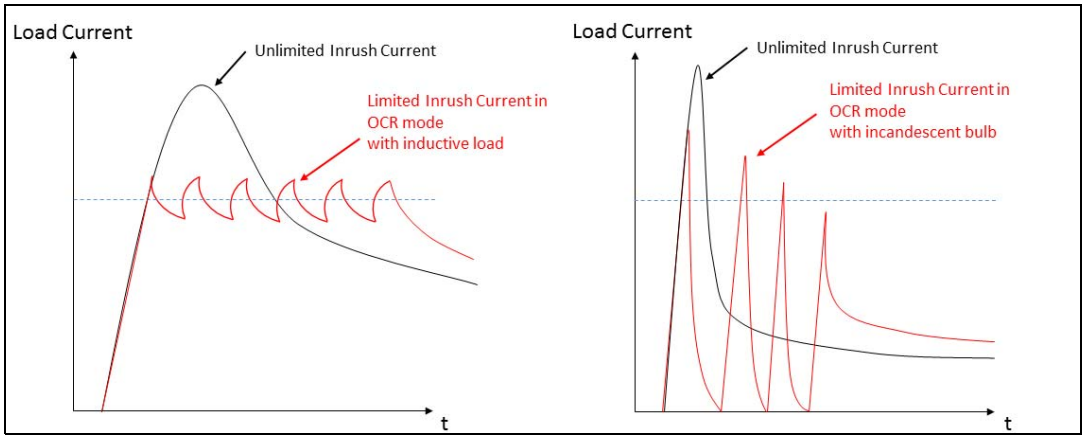
For the 7 outputs from OUT1 to OUT8 and OUT15, besides the Over Current protection feature, a mode called Over Current Recovery (OCR) or Auto Recovery is implemented.

The Over Current Recovery allows to automatically switch ON the Outputs that have been switched OFF after an Over Current detection; this method is needed when loads with start-up currents higher than the Over Current limits need to be driven.

If the outputs are not configured in Over Current Recovery mode, once the load current reaches the Over Current threshold, after the time interval (t_{OCR}), the corresponding status bit in SR 3 is latched and the driver is switched OFF too; in this case the microcontroller has to Read & Clear the according status bits in order to reactivate the corresponding output driver.

If the outputs (from OUT1 to OUT8 and OUT15) are configured in Over Current Recovery mode, once the Over Current condition is detected (i.e. the load current reaches the Over Current threshold), the corresponding driver is switched OFF and hence automatically switched ON after a certain time interval. The Over Current Recovery mode can be individually enabled for a given output, i.e. for each of the Half Bridges (OUT1, OUT2, OUT3 and OUT6) and for each of the High Side drivers (OUT7, OUT8 and OUT15) by setting the corresponding OUTx_OCR (CR7) bit.

Figure 36. Example of programmable soft start function for inductive loads and incandescent bulbs



The Activation sequence of a specific Output driver (switch OFF / switch ON) can be seen as composed by the following 3 timings:

- t_{BLK}
- t_{OCR}
- t_{OFF}

The t_{BLK} time, has been designed to be 40 µs (typ); the t_{OCR} time is the filter time (i.e. current needs to be above the OC threshold for t > t_{OCR} to detect an OC condition).

The t_{OFF} is the time interval in which the output driver is switched OFF.

4.20 Overcurrent Recovery and Short-Circuit detection

Over-Current threshold (latch or auto recovery with thermal expiration) is always active. This condition is detected after a blanking time of t_{BLK} and, in case of auto recovery (OUTx_OCR = 1 for x = 1, 2, 3, 6, 7, 8, 15), also after a filter time t_{OCR}, depending on

OUTxx_OCR_TON_0 (1) (where xx = HB, 7, 8, 15) settings configured in CR8. However, in case of a Short Circuit faster than t_{OCR} or occurring during t_{BLK}, the over-current threshold could not be triggered and the device is not protected. To this aim, for all half-bridges output (OUT1-6), a Short Circuit threshold, higher than the previous one, is also available (see example in *Figure 37*). This condition is detected after a filter time of t_{FSC} and is indicated by the related status bit OUTx_HS_SHORT, OUTx_LS_SHORT (x = 1, 2, 3, 6) in SR4. In case of Short Circuit, the corresponding driver switches off in order to reduce the power dissipation and to protect the integrated circuit (see *Figure 38*).

Short Circuit thresholds can be disabled via SPI (OUTx_SHORT_DIS, in CR7, [12...9])

In case of short circuit detection, a global status bit FE is set (see *Table 89*)

For all the half bridges outputs, when the OCR is enabled, the Short Circuit detection must be enabled or the software strategy described in *Figure 40* of *Section 4.25* must be applied.

Figure 37. Typical working current for a motor connected to OUT1 and OUT6 in low on resistance and related over-current and short circuit thresholds

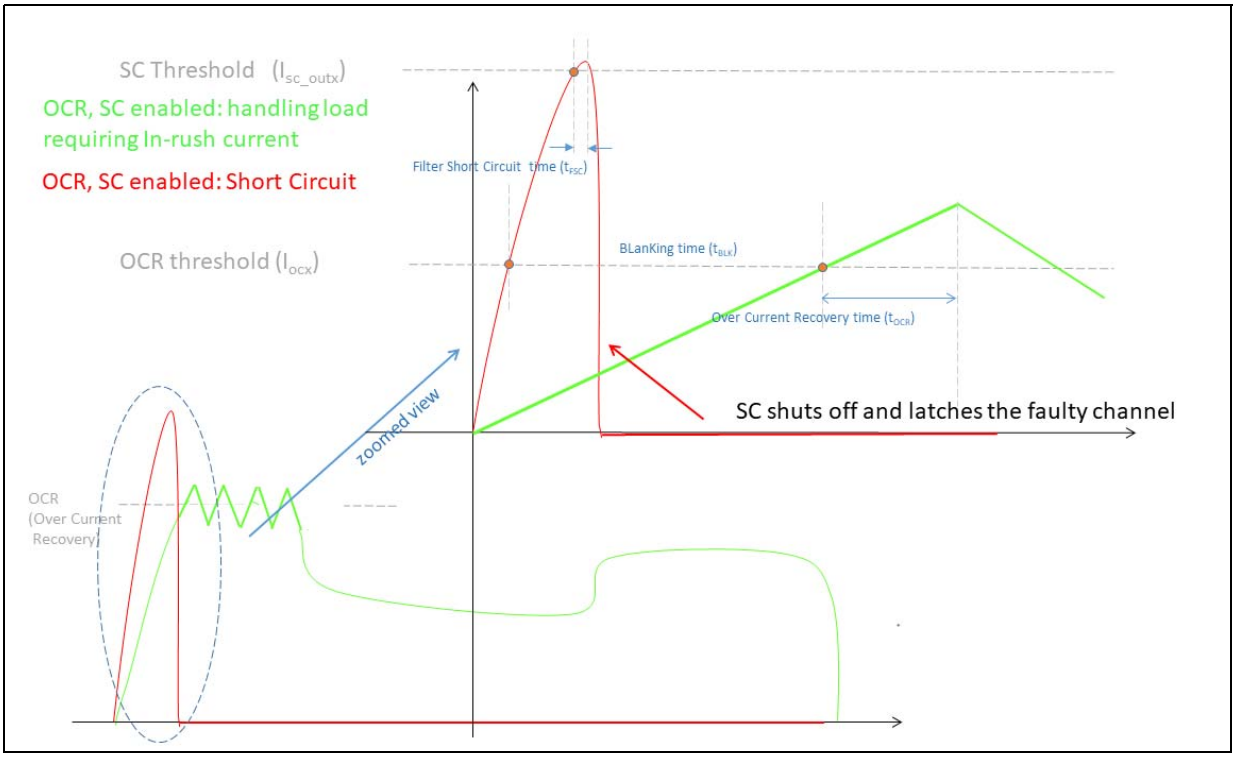
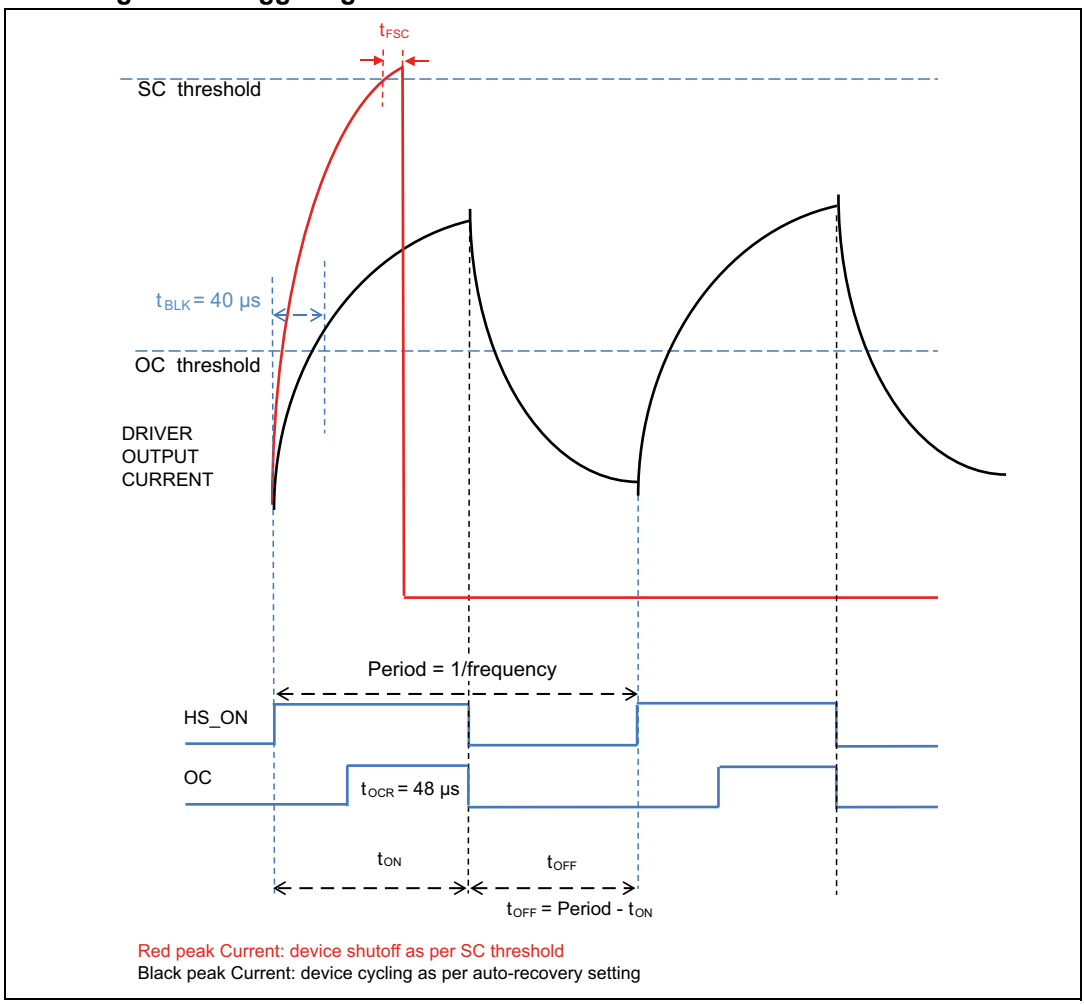


Figure 38. Triggering cases of over-current and short circuit thresholds



4.21 Constant current mode

For the OUT7, OUT8 and OUT9 high side drivers, it is available the CCM (Constant Current Mode) feature, which is conceived to provide a constant current to the related output.

The CCM feature is configurable via SPI, by setting the OUTx_CCM_EN bit (x = 7, 8, 9) in CR9; these bits can be set only if the related driver is in OFF state and when the CCM is enabled, the overcurrent and short circuit detection of the related output is switched OFF while its open load detection is always ON.

The CCM is automatically disabled after an expiration time $t_{CCMtimeout}$.

The allowed sequences are:

- Set OUTx_CCM_EN bit, then turn ON the related driver by SPI or by direct input DIR (the other configurations of the OUTx_3-2-1 are ignored, see *Table 102*): driver starts in CCM for 10ms, then it switches to ON mode or DIR mode and the OUTx_CCM_EN bit is automatically cleared after this 10 ms;
- If OUTx_CCM_EN = 1, the configurations other than “OFF”, “ON” or “DIR” of the OUTx3-2-1-0 (see *Table 102*) are ignored; in that case, the OUTx3-2-1-0 bits are kept

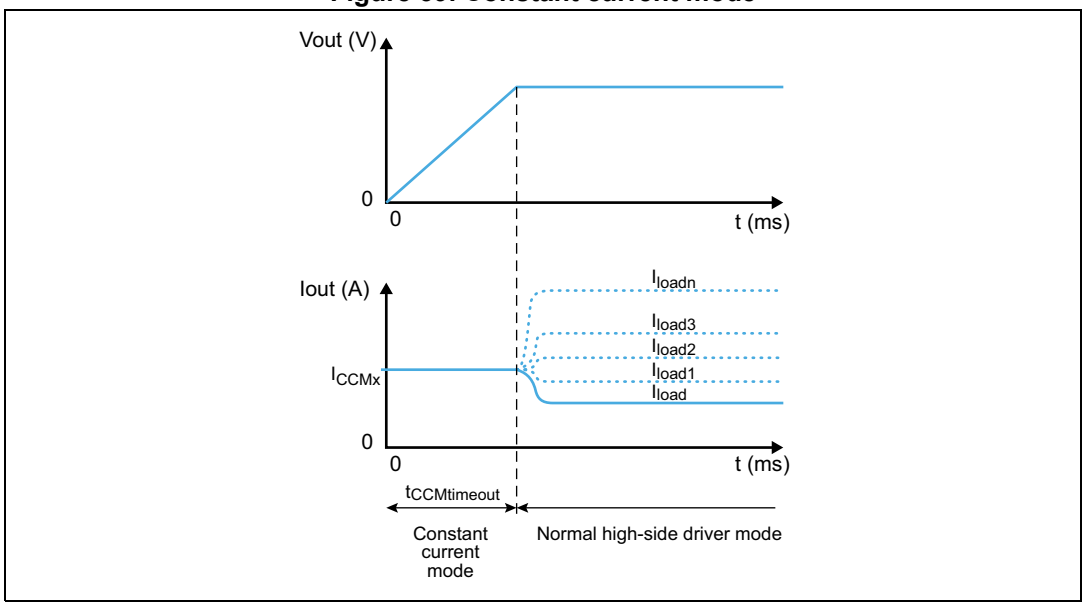
unchanged (at either “0000”=OFF, “0001”=ON or “1110”=DIR) and the SPI_INV_CMD bit (SR2 – 0x32) is set to 1 in order to indicate an invalid setting;

- If OUTx_CCM_EN bit is cleared by the microcontroller before timeout, then the driver is itched to ON mode or DIR mode;
- If OUTx_CCM_EN bit is set after driver has been started in ON, PWM, Timer or DIR modes, then the OUTx_CCM_EN bit is ignored (i.e. OUTx_CCM_EN = 0); in that case OUTx_CCM_EN remains ‘0’ and the SPI_INV_CMD bit (SR2 - 0x32) is set to ‘1’ in order to indicate an invalid setting.

The Short Circuit and Over Current detection are enabled in ON, PWM, timer and DIR modes, but not in Constant Current Mode.

The default value for the OUTx_CCM_EN bit is 0, i.e. the CCM is disabled by default.

Figure 39. Constant current mode



4.22 Current monitor and direct drive input

The current monitor sources a current image of the power stage output current at the current monitor pin CM, which has a fixed ratio (I_{CMr}) of the instantaneous current of the selected high-side driver. The signal at output CM is blanked for t_{cmb} after switching on the driver until correct settlement of the circuitry. The bits CM_SELx (CR 7) define which of the outputs is multiplexed to the current monitor output CM. The current monitor output allows a more precise analysis of the actual state of the load rather than the detection of an open- load or overload condition. For example, it can be used to detect the motor state (starting, free running, stalled). The current monitor output is enabled after the current-monitor blanking time, when the selected output is switched on. If this output is off, the current monitor output is in high impedance mode.

Current monitor output pin is shared with the Direct Input Drive (DIR) and the activation of the two functionalities is obtained by changing the CM_DIR_CONF_x bit (CR7, x = 0, 1).

Four different modalities are identified and detailed in the following *Table 67*.

Table 67. Current Monitor/Direct configurations

CM_DIR_CONF_1	CM_DIR_CONF_0	Description	Pin direction
0	0	CM all the time	Output
0	1	DIR in Standby mode and CM in Active mode	Input / Output
1	0	DIR all the time	Input
1	1	OFF	

4.23 PWM-Mode of the Power-Outputs

Description see*Section 7.3: Status register overview*.

4.24 Cross-current protection

The four half-brides of the device are cross-current protected by an internal delay time. If one driver (LS or HS) is turned off, the activation of the other driver of the same half bridge will be automatically delayed by the crosscurrent protection time. After the crosscurrent protection time is expired the slew-rate limited switch-off phase of the driver is changed to a fast turn-off phase and the opposite driver is turned-on with slew-rate limitation. Due to this behavior, it is always guaranteed that the previously activated driver is completely turned off before the opposite driver starts to conduct.

4.25 Programmable soft-start function to drive loads with higher inrush current

Loads with start-up currents higher than the overcurrent limits (e.g. inrush current of lamps, start current of motors) can be driven by using the programmable soft-start function (i.e. overcurrent recovery mode). Each driver has a corresponding overcurrent recovery bit OUTx_OCR (CR 7). If this bit is set, the device automatically switches the outputs on again after a programmable recovery time. The PWM modulated current will provide sufficient average current to power up the load (e.g. heat up the bulb) until the load reaches operating condition. The PWM frequency is defined by CR7<8:12> setting.

The device itself cannot distinguish between a real overload (e.g. short-circuit condition) and a load characterized by operation currents exceeding the over-current threshold.

Examples are non-linear loads like a light bulb used on the HS outputs or a motor used on the half bridge output with inrush and stall currents that shall be limited by the auto recovery feature.

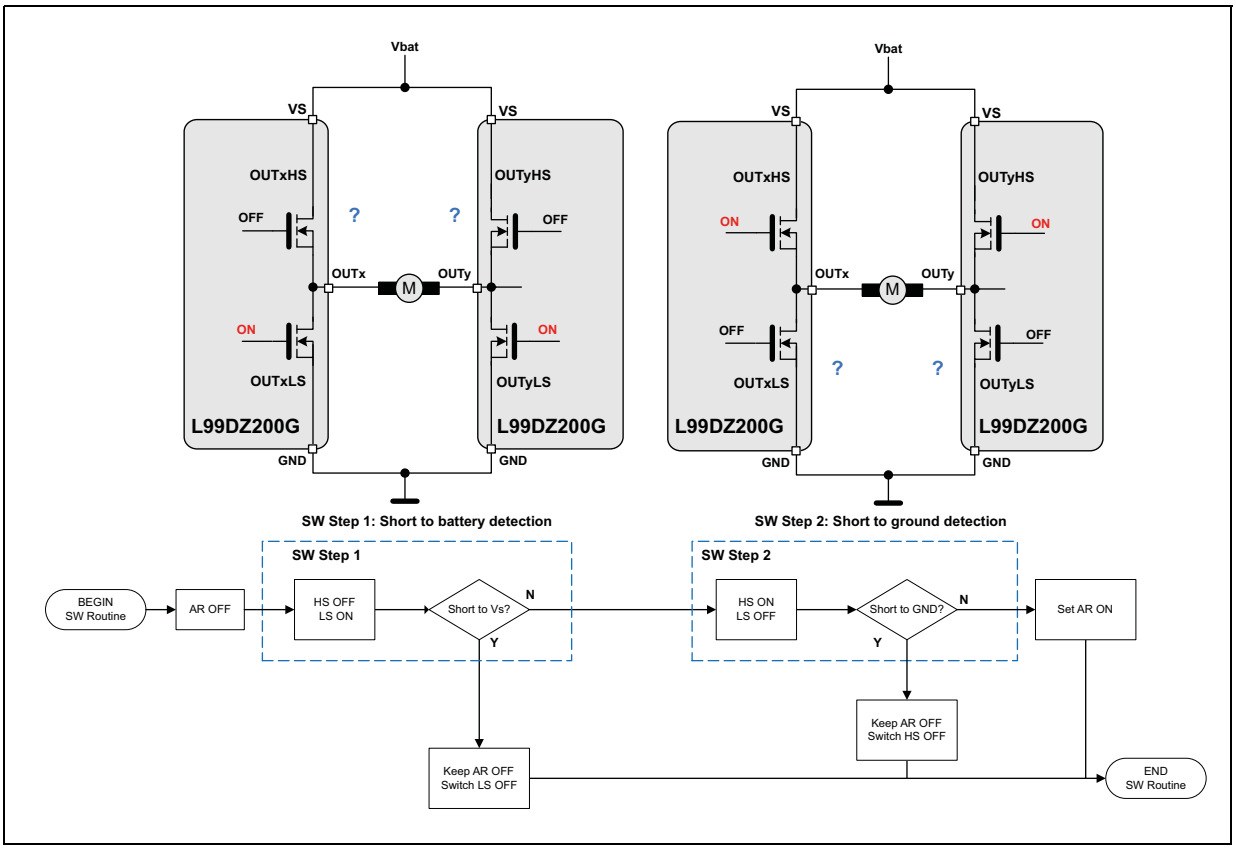
For the bulb, a real overload condition can only be qualified by time. For overload detection the microcontroller can switch on the light bulbs by setting the overcurrent recovery bit for the first e.g. 50 ms. After clearing the recovery bit, the output will be switched off automatically if the overload condition remains.

For the half bridges the high current can be present during all motor activation and another SW strategy must be applied to identify a SC to GND or Supply. Before running the motor e.g. with a first SPI command all bridge LS are switched on (without auto recovery functionality /

cleared overcurrent recovery bit), all HS are switched off and a SC to Battery can be diagnosed. With a next SPI command, all HS are switched on (without auto recovery functionality/ cleared overcurrent recovery bit) and all LS are switched off. In this sequence, a short to GND can be diagnosed. If in both sequences no overload condition is identified, the motor can be run by switching on the relative HS and LS each configured in auto recovery mode (see *Figure 40: Software strategy for half bridges before applying auto-recovery mode*).

Such sequence can be applied before any motor activation to identify SC just before operating the motor (in case the delay due to the 2 additional SPI commands is not limiting the application) or in case of power up of the system respectively applied on a certain time base.

Figure 40. Software strategy for half bridges before applying auto-recovery mode



As soon as an output reaches auto-recovery condition, OUTx_OCR_ALERT (SR 4) is set. The Alert bit indicates that an overload condition (load in-rush, short-circuit, etc) is present.

4.26 H-bridge control

The PWMH1y, PWMH2y inputs and the DIRHy bits (DIRHA in CR10, DIRHB in CR21) control the drivers of the external H-bridge transistors (y = A, B); independently from the PWMH frequency (f_{PWMH}) applied by the µC to control the H-bridges A and B, the PWMH On-time shall be higher than 250ns. In Single Motor mode, bit DMy (Config Reg = 0), the motor direction can be chosen with the control bit (DIRHy), the duty cycle and frequency with the PWMH1y input. With the SPI bits SD1y (CR 10) and SDS1y (CR 10) four different

freewheeling modes (via drivers in the active cases or via diodes in the passive cases) can be selected using the high-side or the low-side transistors.

Alternatively, the external H-bridges can be driven in half bridge mode (Dual mode). By setting the dual mode bit DMy (Config Reg) = 1, both the half-bridges of the H-bridge y can be controlled independently.

Table 68. H-bridge y (y = A, B) control truth table in Single mode (DMy = 0)

	Control pins		Control bits							Failure bits					Output pins				
Nb	PWMH1y	PWMH2y	DIRHy	HENy	DMy	SD1y	SDS1y	SD2y	SDS2y	CP_LOW	VS_OV	VS_UV	DS	TSD1	GH1y	GL1y	GH2y	GL2y	
1	x	x	x	0	x	x	x	x	x	x	x	x	x	x	RL	RL	RL	RL	H-bridge y disabled
2	x	x	x	1	0	x	x	x	x	1	0	0	0	0	RL	RL	RL	RL	Charge pump voltage too low
3	x	x	x	1	0	x	x	x	x	0	x	x	x	1	RL	RL	RL	RL	Thermal shutdown
4	x	x	x	1	0	x	x	x	x	0	1	0	0	0	L	L	L	L	Overvoltage
5	x	x	x	1	0	x	x	x	x	0	0	0	1	0	L (1)	L(1)	L(1)	L(1)	Short-circuit(1)
6	1	x	0	1	0	x	x	x	x	0	0	0	0	0	L	H	H	L	Bridge y H2/L1 on
7	0	x	x	1	0	0	0	x	x	0	0	0	0	0	L	H	L	H	Active freewheeling LS1 and LS2 on
8	0	x	0	1	0	0	1	x	x	0	0	0	0	0	L	H	L	L	Passive freewheeling through LS2 diode
9	0	x	1	1	0	0	1	x	x	0	0	0	0	0	L	L	L	H	Passive freewheeling through LS1 diode
10	1	x	1	1	0	x	x	x	x	0	0	0	0	0	H	L	L	H	Bridge y H1/L2 on
11	0	x	x	1	0	1	0	x	x	0	0	0	0	0	H	L	H	L	Active freewheeling HS1 and HS2 on
12	0	x	0	1	0	1	1	x	x	0	0	0	0	0	L	L	H	L	Passive freewheeling through HS1 diode
13	0	x	1	1	0	1	1	x	x	0	0	0	0	0	H	L	L	L	Passive freewheeling through HS2 diode

1. Only the half bridge (low-side and high-side), in which one MOSFET is in short-circuit condition is switched off. Both MOSFETs of the other half bridge remain active and driven by DIRHy control bit and PWMHy pin.

Table 69. H-bridge y (y = A, B) control truth table in Dual Mode (DMy = 1) for the leg x (x= 1, 2)

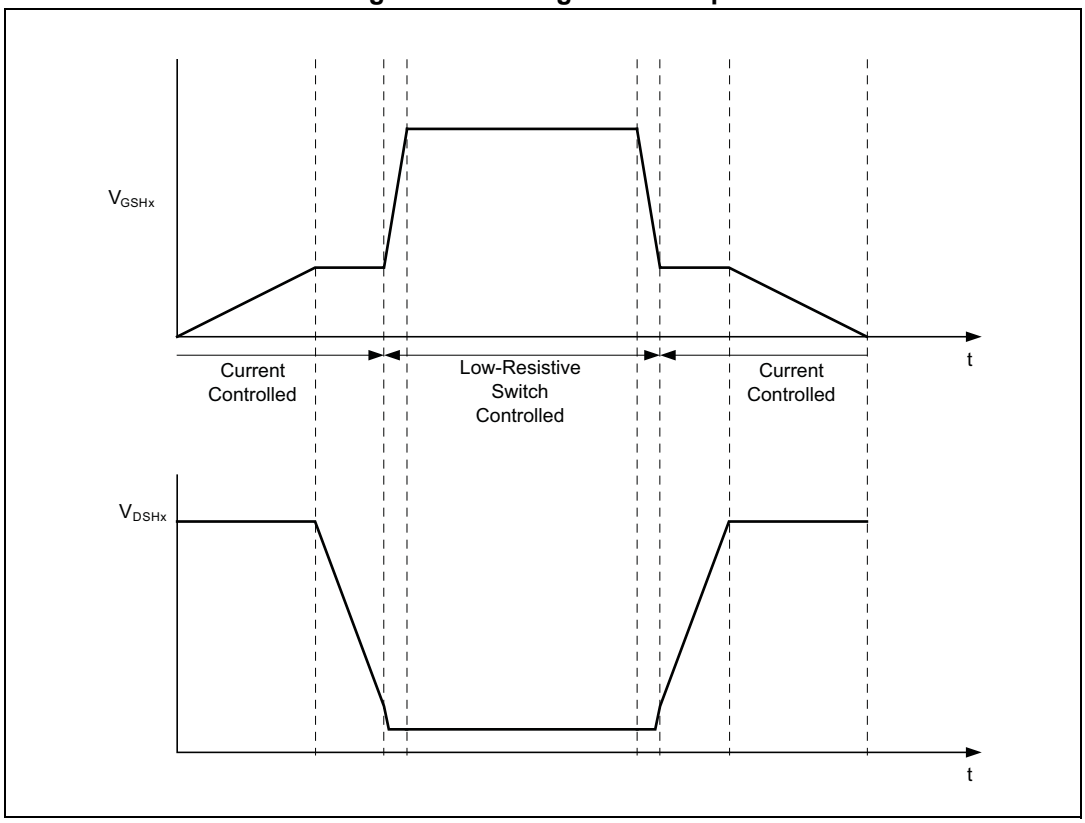
	Control pin	Control bits					Failure bits					Output pin		Comment
Nb	PWMHxy	HENy	DMy	DIRHy	SDxy	SDSxy	CP_LOW	VS_OV	VS_UV	DS	TSD1	GHxy	GLxy	
1	0	1	1	x	0	0	0	0	0	0	0	L	H	Active freewheeling LS
2	1	1	1	x	0	0	0	0	0	0	0	H	L	DRIVE HS
3	0	1	1	x	1	0	0	0	0	0	0	H	L	Active freewheeling HS
4	1	1	1	x	1	0	0	0	0	0	0	L	H	DRIVE LS
5	0	1	1	x	0	1	0	0	0	0	0	L	L	Passive freewheeling
6	1	1	1	x	0	1	0	0	0	0	0	H	L	DRIVE HS
7	0	1	1	x	1	1	0	0	0	0	0	L	L	Passive freewheeling
8	1	1	1	x	1	1	0	0	0	0	0	L	H	DRIVE LS

During watchdog long-open window, the H-bridge drivers are forced off until the first valid watchdog trigger in window mode (setting TRIG = 0 during safe window). The Control Registers remain accessible during long open window.

4.27 H-Bridge Driver Slew-Rate Control

The rising and falling slope of the drivers for the external high-side Power-MOS can be slew rate controlled. If this mode is enabled the gate of the external high-side Power-MOS is driven by a current source instead of a low-impedance output driver switch as long as the drain-source voltage over this Power-MOS is below the switch threshold. The current is programmed using the bits SLEW_x<4:0> (CR 10), which represent a binary number. This number is multiplied by the minimum current step. This minimum current step is the maximum source-/sink-current ($I_{GHxrmax}$ / $I_{GHxfmax}$) divided by 31. Programming SLEW_x <4:0> to 0 disables the slew rate control and the output is driven by the low-impedance output driver switch.

Figure 41. H-bridge GSHx slope



4.28 Resistive low

The resistive output mode protects the devices and the two H-bridges in the standby mode and in some failure modes (thermal shutdown TSD1 (SR 1), charge pump low CP_LOW (SR 2) and DI pin stuck at '1' SPI_INV_CMD (SR 2). When a gate driver changes into the resistive output mode due to a failure a sequence is started. In this sequence the concerning driver is switched into sink condition for 32 µs to 64 µs to ensure a fast switch-off of the H-bridge transistor. If slew rate control is enabled, the sink condition is slew-rate controlled. Afterwards the driver is switched into the resistive output mode (resistive path to source).

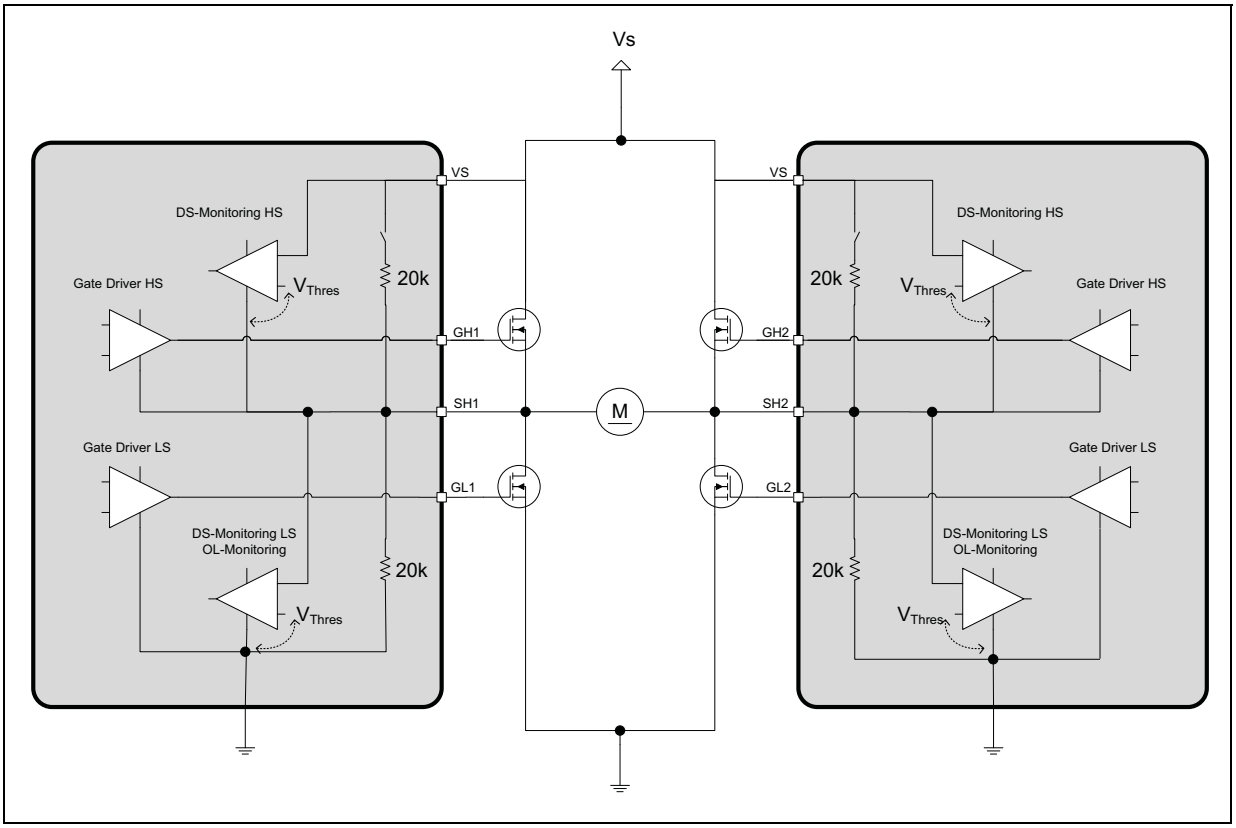
4.29 Short circuit detection / drain source monitoring

The Drain - Source voltage of each activated external MOSFET of the H-bridges A and B is monitored by comparators to detect shorts to ground or battery. If the voltage-drop over the external MOSFET exceeds the configurable threshold voltage V_{SCd_HB} (DIAG_A_x (CR 10) for H-bridge A and DIAG_B_x (CR23) for H-bridge B) for longer $t > t_{SCd\_HB}$ the corresponding gate driver switches off the external MOSFET and the corresponding drain source monitoring flag DS_MON_x (SR 2) is set. The DSMON_x bits have to be cleared through the SPI to reactivate the gate drivers. This monitoring is only active while the corresponding gate driver is activated. If a drain-source monitor event is detected, the corresponding gate-driver remains activated for at maximum the filter time.

When the gate driver switches on, the drain-source comparator requires the specified settling time until the drain-source monitoring is valid. During this time, this drain-source

monitor event may start the filter time. The threshold voltage V_{SCd_HB} can be programmed using the SPI bits DIAG_A_x (CR 10) or DIAG_B_x (CR 23).

Figure 42. H-bridge diagnosis



4.30 H-Bridge-Monitoring in Off-Mode

The drain source voltages of the two H-bridges A and B driver external transistors can be monitored, while the transistors are switched off. If either bit OL_H1L2_X or OL_H2L1_X (CR 10 for X=A, CR23 for X=B) is set to 1, while bit HEN_X (CR 1) = 1, the H-drivers X (A or B) enter resistive low mode and the drain-source voltages can be monitored. Since the pull-up resistance is equal to the pull-down resistance on both sides of the bridge, a voltage of 2/3 V_S on the pull-up high side and 1/3 V_S on the low- side is expected, if they drive a low-resistive inductive load (e.g. motor). If the drain source voltage on each of these Power-MOS is less than 1/6 V_S, the drain-source monitor bit of the associated driver is set. The open-load filter time is t_{OL_HB}.

Figure 43. H-bridge open-load-detection (no open-load detected)

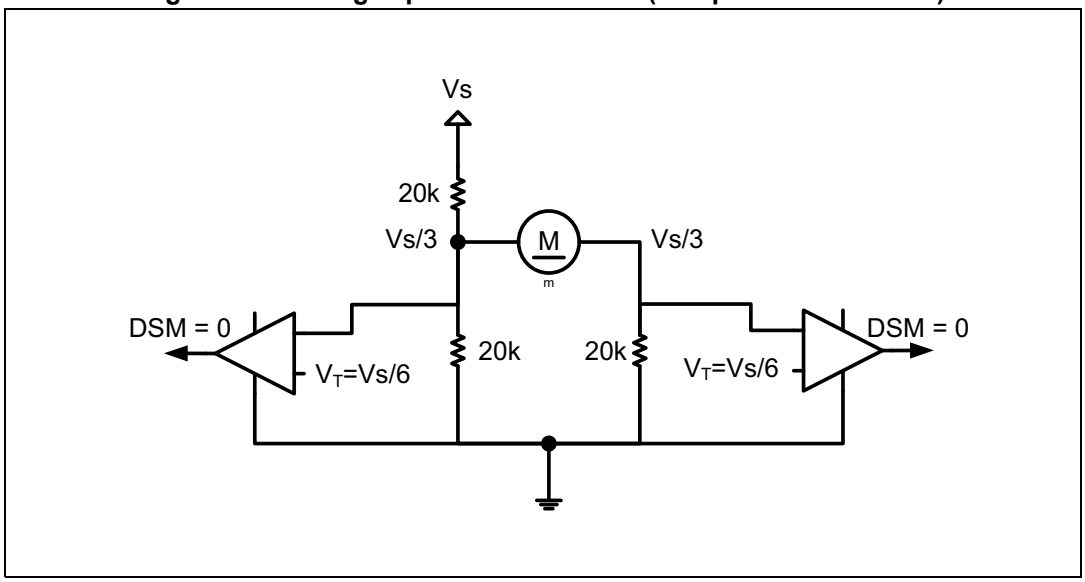


Figure 44. H-bridge open-load-detection (open-load detected)

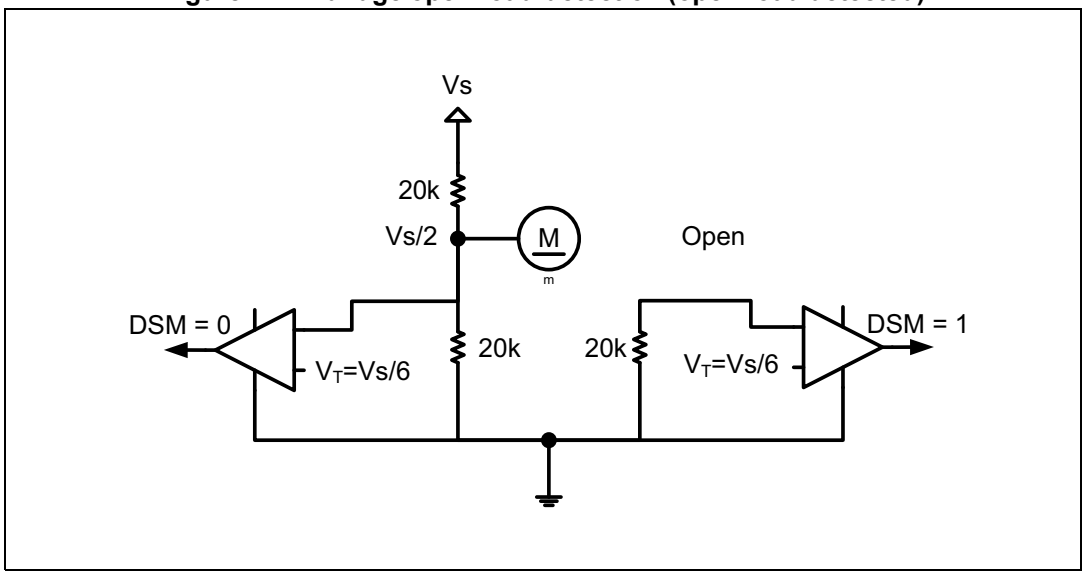


Figure 45. H-bridge open-load-detection (short to ground detected)

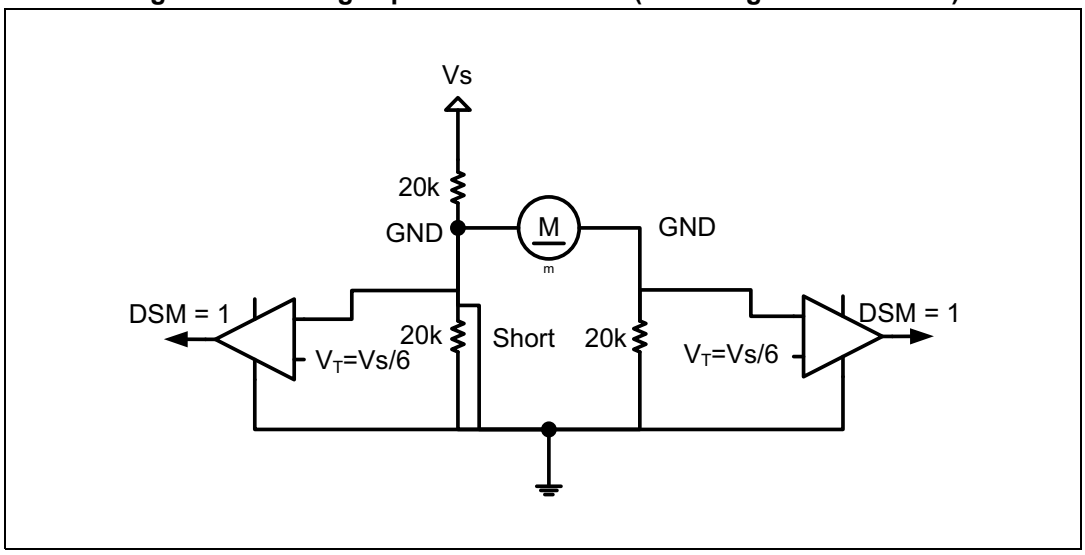
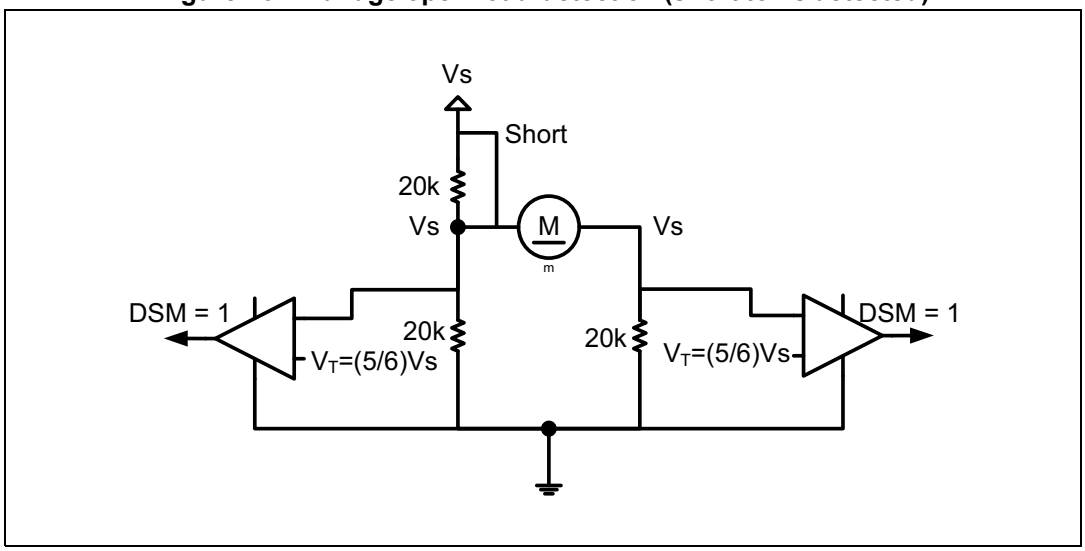


Figure 46. H-bridge open-load-detection (short to Vs detected)



In this specific case the outputs of the 2 comparators are inverted to be compliant to *Table 70: H-bridge monitoring in off-mode* (Nb = 9).

Table 70. H-bridge monitoring in off-mode

	Control bits			Failure bits		Comments
Nb	OL H1L2	OL H2L1	H OLTH High	DSMON LS1	DSMON LS2	
1	0	0	0	0	0	Drain-Source monitor disabled
2	1	0	x	0	0	No open-load detected
3	1	0	0	0	1	Open-load SH2
4	1	0	0	1	1	Short to GND

Table 70. H-bridge monitoring in off-mode (continued)

	Control bits			Failure bits		Comments
Nb	OL H1L2	OL H2L1	H OLTH High	DSMON LS1	DSMON LS2	
5	1	0	1	1	1	Short to VS
6	0	1	x	0	0	No open-load detected
7	0	1	0	1	0	Open-load SH1
8	0	1	0	1	1	Short to GND
9	0	1	1	1	1	Short to VS

What reported in this chapter applies only to single motor H-bridge configuration; i.e. in the case one H-bridge drives only one motor.

4.31 Programmable cross current protection

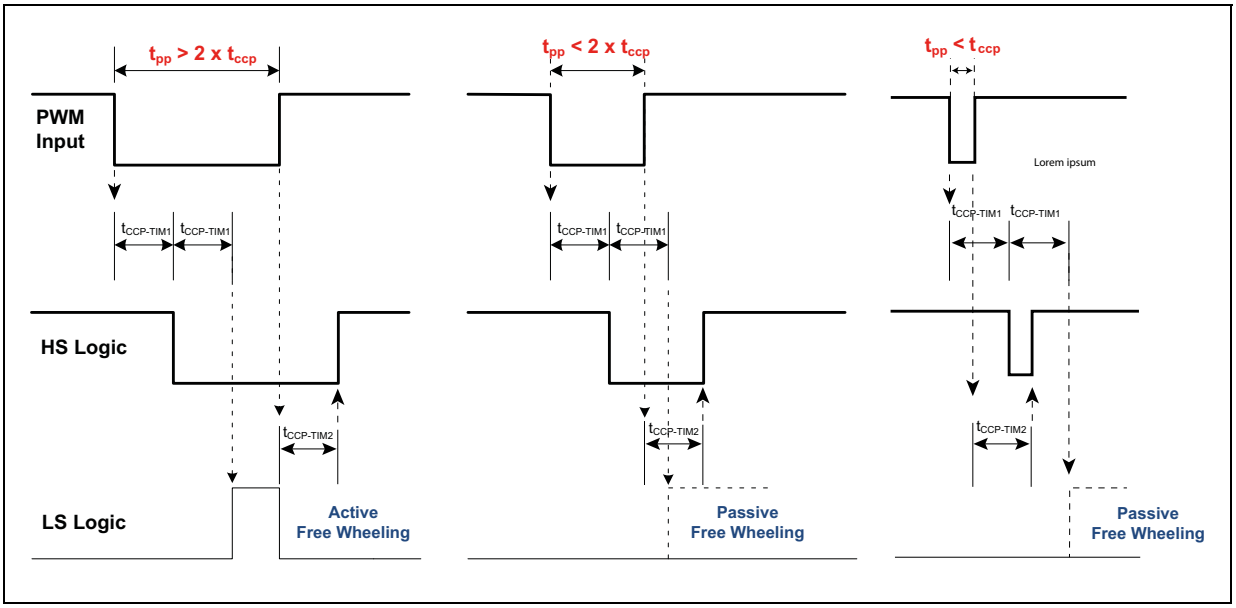
The external Power MOSFETs transistors in H-bridge A and B (two half-bridge for each H-bridge) configuration are switched on with an additional delay time t_{CCP} to prevent cross current in the half bridge. The cross current protection time t_{CCP} can be programmed with the SPI bits COPT_x_A<3:0> (CR 10 for H-bridge A) or COPT_x_B <3:0> (CR 15 for H-bridge B). The timer is started when the gate driver is switched on in the device.

The PWMH module has 2 timers to configure locking time for high-side and freewheeling low-side. The programmable time $t_{CCP\text{-}TIM1}$ / $t_{CCP\text{-}TIM2}$ is the same. Sequence for switching in PWM mode is the following:

- HS switch off after locking $t_{CCP\text{-}TIM1}$
- LS switch on after 2nd locking $t_{CCP\text{-}TIM1}$

HS switch on after locking $t_{CCP\text{-}TIM2}$ which starts with rising edge on PWM input.

Figure 47. PWMH cross current protection time implementation



4.32 Power window H-bridge safety switch off block

The two LS Switches LSA_FSO and LSB_FSO are intended to be used to switch off the gates of the two external high-side MOSFETs in the power window h-bridges (A and B) if a fatal error happens. This block must work also in case the MOSFET driver and the relative control blocks on the chip are destroyed. Therefore, it is necessary to have a complete separated safety block on the device, which has its own supply and GND connection, separated from the other supplies and GNDs. In the block, an own voltage regulator and an oscillator are implemented.

The safety block is surrounded by a GND isolation ring realized by deep trench isolation. The LS driver must work down to a lower voltage than the other circuits. The block has its own internal supply and an own oscillator for monitoring the failure signals (WWD, V1 fail, SPI fail & Tj) which are Manchester encoded and decoupled by high ohmic resistances. In case of fail-safe event, both LS switches LSA_FSO and LSB_FSO are switched on.

In case of entering V1_Standby mode or VBAT_Standby mode both fail safe low-side switches are switched on to minimize the current drawn by the fail-safe block (e.g. oscillator is switched off and Manchester Encoding is deactivated). Short circuit protection to V_S is active in both standby modes limiting the current to I_{OLimit} for a filter of t_{SCF}.

After this filter time the fail-safe switches are switched off and LSx_FSO_OC (SR 3) is set. To reactivate the low-side functionality this bit has to be set back by a read and clear command. In case of V_S loss the fail-safe switches are biased by their own output voltage to turn on the low-side switches down to VOUT_max.

To allow verification of the Fail-Safe path, the low-side switches LSA_FSO and LSB_FSO can be turned on by SPI (Configuration Register 0x3F bit 4: FS_FORCED).

Figure 48. LSx_FSO: low-side driver "passively" turned on, taking supply from output pin (if main supply fails), can guarantee VLSx_FSO < VOUT_max

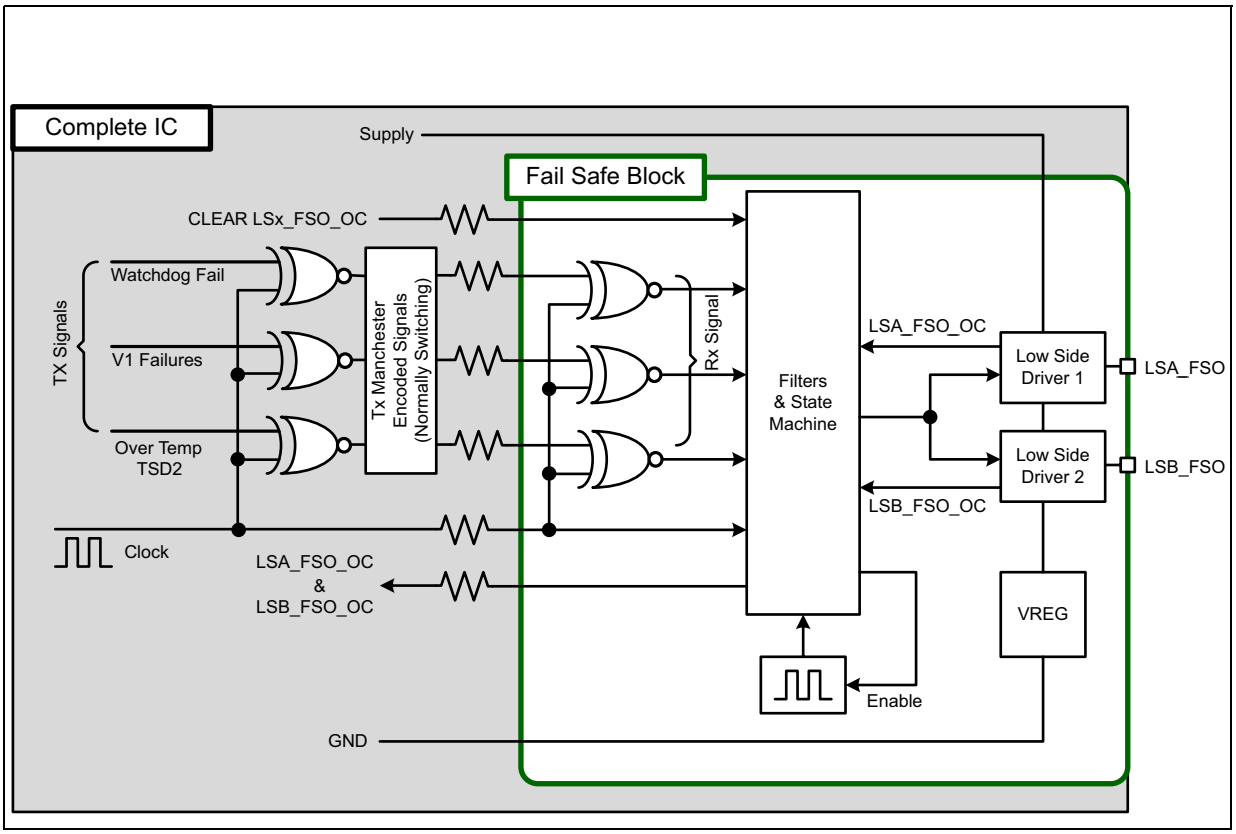
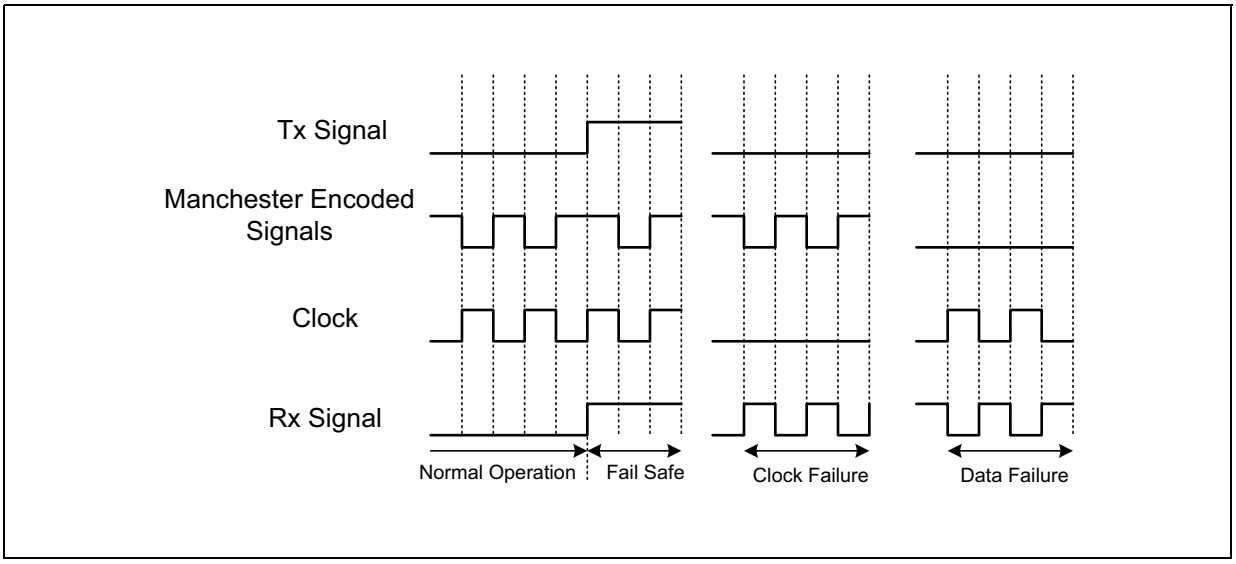


Figure 49. Safety concept



4.33 Generator mode

Generator mode allows the L99DZ200G h-bridge drivers to autonomously switch ON all the external LS MOSFETs of both h-bridges (A and B) when an overvoltage on the VS line is detected. Main purpose of these concurrent activations is to immediately block at the same time both the DC motors connected to the 2 external full bridges (braking function).

Generator Mode is by default enabled at the startup of the device and it is controlled by the GENERATOR_MODE_EN bit in CR22 (0x16); in case the VS OV occurs during standby modes and the generator mode is enabled, the VS_OV_WAKEUP bit in the SR1 (0x31) identifies the OV as source of the wakeup.

Generator mode works when L99DZ200G is in Active, in V1_Standby and in VBAT_Standby modes. Fail safe low side circuitry has not to be activated/connected if the Generator mode will be used

4.33.1 Generator Mode in Active Mode

The below reported *Table 71* shows the wake UP True table for the Generator Mode when the device is in active mode:

Table 71. Wake UP for Generator Mode

L99DZ200G Status	GENERATOR _MODE_EN	LS MOSFETs state after V_S OV condition	Notes
Active	1	ON if $V_S > V_{SOV}$	Monitoring is done by the "Vs Monitor"
		Controlled by the h-bridge drv if $V_S < V_{SOV}$	
	0	Controlled by the h-bridge drv	

In Active Mode, Generator Mode is a live functionality, i.e. the Vs is continuously monitored by a "V_S Monitor". In case the V_S OV is detected, GL1y and GL2y (y = A, B) are switched ON; they are switched OFF as soon as the V_S OV is no more detected.

When the Generator Mode is enabled (GENERATOR_MODE_EN=1), the configuration of the h-bridge drivers A and B can be changed even when the V_S OV is occurring. The h-bridges A and B will recover the normal h-bridge drive once the V_S OV ends; moreover, during this V_S OV situation the LS MOSFETs continues to be ON even if a TSD1 or a TSD2 or a Fail Safe event occurs.

4.33.2 Generator Mode in Standby Modes

In V1_Standby or in VBAT_Standby modes, a "V_S OV Detector" is used to detect the occurrence of a Vs OV; in this case the thresholds are V_{SOV_DET} (see parameters A.185, A.186 and A.187 in *Table 7*).

When Vs > V_{S_OVDET} the device is firstly put in Active mode and then the "Vs Monitor" is activated; all this sequence lasts (t_{OVUV_FILT} + t_{FOV}) plus the time needed to start the oscillator at V_{SOV_DET} threshold (around 10 µs) plus the time needed to stabilize the reference voltage (around 10 µs). This means that the V_{SOV} shall be present for a minimum of 148 µs to start the braking function and set the VS_OV_WAKEUP bit (SR1).

The below reported *Table 72: Wake UP for Generator Mode* shows the Wake UP True table for the Generator Mode when the device is in V1_Standby or in VBAT_Standby mode:

Table 72. Wake UP for Generator Mode

L99DZ200G Status	GENERATOR _MODE_EN	Wake UP when a V_S OV occurs	LS MOSFETs state after V_S OV condition ($V_S > V_{SOV\_det}$)	Notes
V1_Standby or VBAT_Standby	1	Yes	OFF (1)	added around 1 µA conso
	0	No	OFF	

1. Generator Mode wake up at Vs OverVoltage by VS OV Detector (low consumption, 1 µA)

In Standby modes:

- if the Vs OV is detected, SPI writing to enter in Standby modes will be ignored and a SPI Error will be generated; in this case the SPI_INV_CMD bit (SR2 - 0x32) is set to 1 in order to indicate an invalid setting;
- if the Vs OV disappears, a new SPI access will be needed to enter in Standby modes.

4.34 Heater MOSFET Driver

The Heater MOSFET Driver stage is controlled by control bit GH (CR 5). The driver contains two diagnosis features to indicate short-circuit in active mode (external MOSFET switched on) and open-load in off state (External MOSFET switched off).

Short circuit detection in on state is realized by monitoring the drain source voltage of the activated external MOSFET by a comparator to detect a short-circuit of SH_{heater} to ground. If the voltage-drop over the external MOSFET exceeds the programmed threshold voltage V_{SCd_HE} for longer than the drain-source monitor filter time t_{SCd_HE} the gate driver switches off the external MOSFET and the corresponding drain source monitoring flag DSMON_HEAT (SR 5) is set. The drain source-monitoring bit has to be cleared by SPI to reactivate the gate driver. The drain source monitoring is only active while the gate driver is activated. If a drain source monitoring event is detected, the gate-driver remains activated for the maximum filter time. The threshold voltage can be programmed by SPI bits GH_THx (CR 10).

Open-load detection in off state is realized by monitoring the voltage difference between SH_{heater} and GND and supplying SH_{heater} by a pull up current source that can be controlled by SPI bit GH_OL_EN (CR 11). When no load is connected to the external MOSFET source, the voltage will be pulled to V_S and in case of exceeding the threshold $V_{OLheater}$ for a time longer than the open-load filter time t_{OL_He} the open-load bit GH_OL (SR 5) will be set.

Figure 50. Heater MOSFET open-load and short-circuit to GND detection

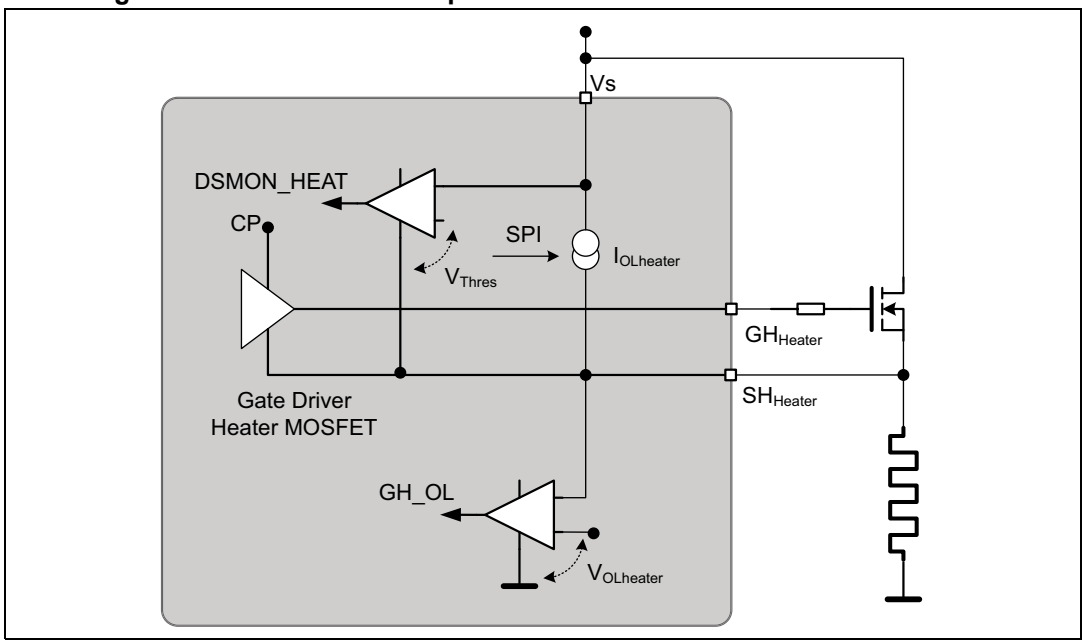


Table 73. Heater MOSFET control truth table

	Control bit	Failure bits					Output pin	Comment
Nb	GH ON/OFF	CP_LOW	VS_OV	VS_UV	DS	TSD1	GH_{heater}	
1	x	1	x	x	x	x	RL	Charge pump voltage too low
2	x	0	x	x	x	1	RL	Thermal shutdown
3	x	0	1	x	x	0	L	Overload
4	1	0	0	x	1	0	L	Short-circuit condition
5	x	0	0	1	0	0	L	Undervoltage
6	1	0	0	0	0	0	H	Heater MOSFET driver
7	0	0	0	0	0	0	L	Heater MOSFET driver

Note: RL = resistive low, L = active low, H = active high.

4.35 Controller of electro-chromic glass

The voltage of an electro-chromic element connected at pin ECV can be controlled to a target value, which is set by the bits EC_x <5:0> (CR 11). Setting bit ECON (CR 11) enables this function. An on-chip differential amplifier and an external MOS source follower (with its gate connected to pin ECDR) driving the electro-chrome mirror voltage at pin ECV, form the control loop. The drain of the external MOS transistor is supplied by OUT10. A diode from pin ECV (anode) to pin ECDR (cathode) has been placed on the chip to protect the external MOS source follower. A capacitor of at least 5 nF has to be added to pin ECDR for loop-stability.

The target voltage is binary coded with a full-scale range of 1.5 V. If bit ECV_HV (Config Reg) is set to 0, the maximum controller output voltage is clamped to 1.2 V without changing the resolution of bits EC_x<5:0> (CR 11). When programming the ECV low-side driver ECV_LS (CR 11) to on-state, the voltage at pin ECV is pulled to ground by a 1.6 Ω low-side switch until the voltage at pin ECV is less than d_{VECVhi} higher than the target voltage (fast discharge). The status of the voltage control loop is reported via SPI. Bit ECV_VHI (SR 6) is set, if the voltage at pin ECV is higher, whereas Bit ECV_VNR (SR 6) is set, if the voltage at pin ECV is lower than the target value. Both status bits are valid, if they are stable for at least the filter time t_{FECVNR} and t_{FECVHI}. Since OUT10 is the output of a high-side driver, it contains the same diagnose functions as the other high-side drivers (e.g. during an overcurrent detection, the control loop is switched off). In electro-chrome mode, OUT10 cannot be controlled by PWM mode. For EMS reasons, the loop capacitor at pin ECDR as well as the capacitor between ECV and GND have to be placed to the respective pins as close as possible (see *Figure 51: Electro-chrome control block* for details).

Pin ECDR is pulled resistively ($R_{ECDRDIS}$) to ground while not in electro-chrome mode. EC glass control behavior in case of failure on OUT10:

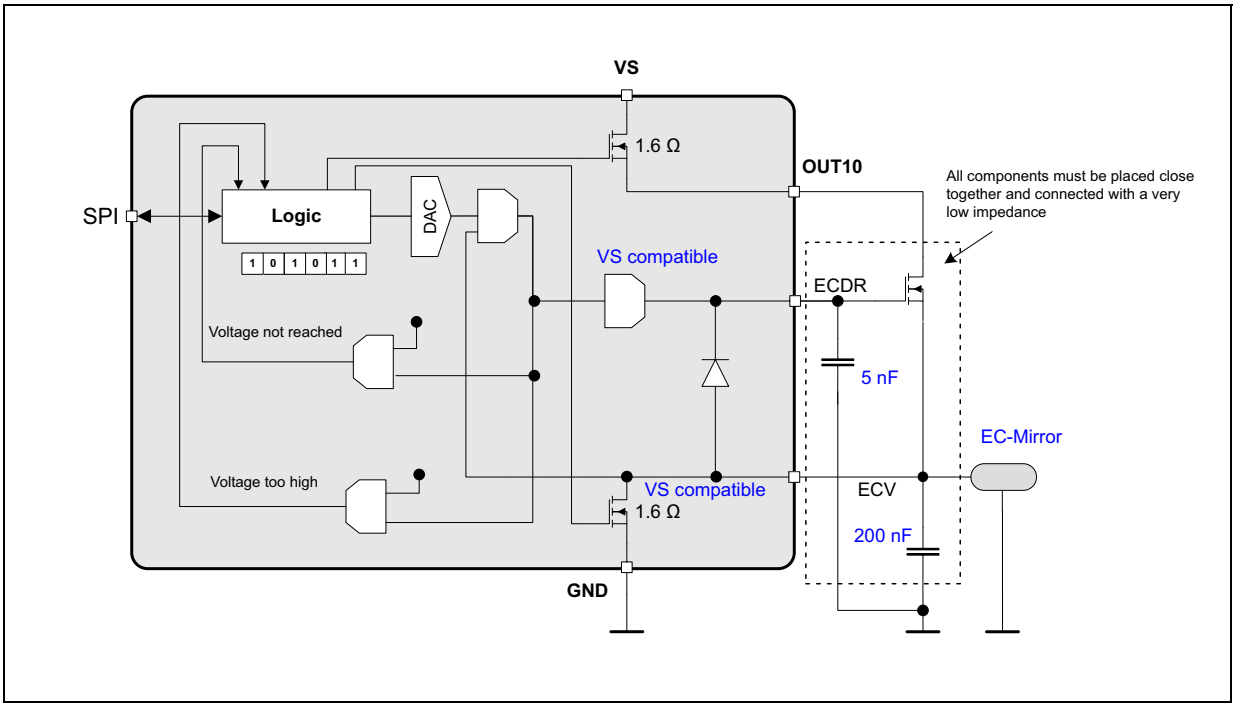
ECON (CR11) = 1 (EC glass control enabled)

- OUT10 is turned ON
- OUT10 settings in CR5 are ignored (PWM, DIR, TIMERx)
- OUT10 settings in CR5 are recovered when ECON is set to 0.

In case of a failure on OUT10 while ECON = 1 (overcurrent, V_S overvoltage /undervoltage, TSD1)

- OUT10 is turned OFF (regardless of VS_OV_SD_EN and VS_UV_SD_EN in CR3)
- DAC is reset: EC_x (CR11) set to ‘000000’
- ECDR pin is pulled to GND
- ECON (CR11) remains ‘1’
- ECV_LS (CR11) remains as programmed Re-start of EC control after OUT10 failure
- Read&Clear or automatic restart (if CR3 Vs_LOCK_EN = 0)
- Write EC_x (CR11)

Figure 51. Electro-chrome control block



4.36 Temperature warning and shutdown

If any of the cluster (see *Section 4.37*) junction temperatures rises above the temperature warning threshold TW, the temperature warning flag TW (SR 2) is set after the temperature warning filter time t_{jtft} and can be read via SPI. If the junction temperature increases above the temperature shutdown threshold (TSD1), the thermal shutdown bit TSD1 (SR 1) is set and the power transistors of all output stages are switched off to protect the device after the thermal shutdown filter time. The gates of the H-bridge and the heater MOSFET are discharged by the 'Resistive Low' mode. After these bits have been cleared, the output stages are reactivated. If the temperature is still above the thermal warning threshold, the thermal warning bit is set after t_{jtft}. Once this bit is set and the temperature is above the temperature shutdown threshold, temperature shutdown is detected after t_{jtft} and the outputs are switched off. Therefore, the minimum time after which the outputs are switched off after the bits have been cleared in case the temperature is still above the thermal shutdown threshold is twice the thermal warning/ thermal shutdown filter time t_{jtft}.

4.37 Thermal clusters

In order to provide an advanced on-chip temperature control, the power outputs are grouped in six clusters with dedicated thermal sensors. The sensors are suitably located on the device (see *Figure 52: Thermal clusters identification*). In case the temperature of an output cluster reaches the thermal shutdown threshold, the outputs assigned to this cluster are shut down (all other outputs remain active). Each output cluster has a dedicated temperature warning and shutdown flag (SR 6) and the cluster temperature can be read out by SPI.

Hence, the thermal cluster concept allows to identify a group of outputs in which one or more channels are in overload condition.

If thermal shutdown has occurred within an output cluster, or if temperature is rising within a cluster, it may be desired to identify which of the output (s) is (are) determining the temperature increase. An additional evaluation, based on current monitoring and cluster temperature read-out, supports identification of the outputs mainly contributing to the temperature increase. The cluster temperatures are available in SR 7, SR 8 and SR 9 and can be calculated from the binary coded register value using the following formula:

Decimal code = (350 – Temp) / 0.488

Example:

T = -40 °C => decimal code is 799 (0x31F) T = 25 °C => decimal code is 666 (0x29A)

Thermal clusters can be configured using bit TSD_CONFIG (Config Reg):

- Standard mode (default): as soon as any cluster reaches thermal threshold the device is switched off. V1 regulator remains on and is switched off reaching TSD2.
- Cluster mode: only the cluster that reaches shutdown temperature is switched off.

If Cluster Th_CL6 (global) or Cluster Th_CL5 (Voltage Regulators) reaches TSD1, the whole device is OFF (beside V1).

Note: Clusters related to power outputs (clusters 1 to 4, see Figure 52: Thermal clusters identification) will be managed digitally only, by means of the ADC conversion of related thermal sensors, while clusters 5 and 6 will be managed in an analog way (comparators) since ADC can be off, e.g. in V1_Standby mode. Temperature reading provided by ADC may differ from real junction temperature of a specific output due to spatial placement of thermal sensor. Such an effect is more visible during fast thermal increases of junction temperature. For some of the Power outputs, located between two different sensors, it may happen that temperature raising also affects the adjacent Cluster.

Figure 52. Thermal clusters identification

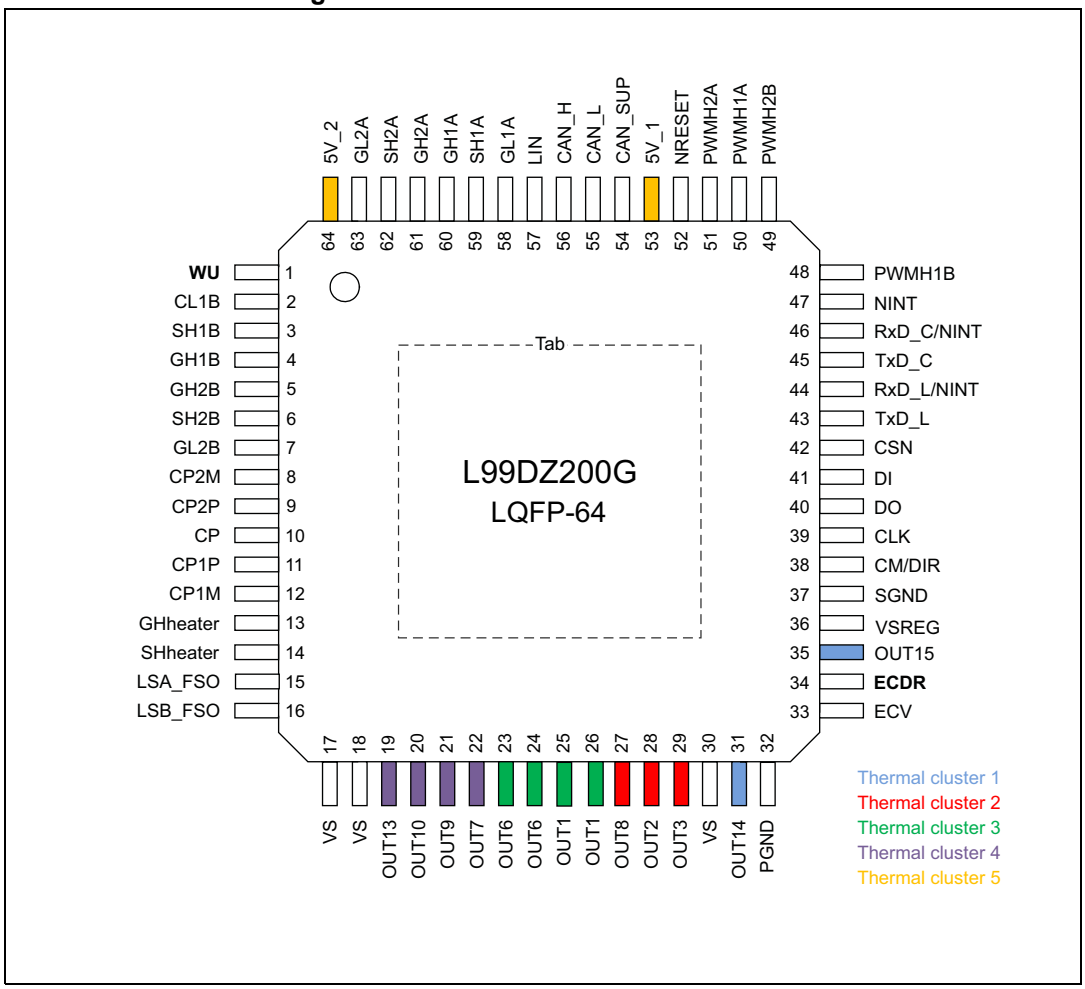


Table 74. Thermal cluster definition

Th_CL1	Th_CL2	Th_CL3	Th_CL4	Th_CL5	Th_CL6
OUT14+OUT15	Mirror-x+ Mirror-y + OUT8	Folder (OUT1+OUT6)	10W driver high ohmic channels	VREG 1 VREG 2	Global
TW & TSD1 Both digitally managed	TW & TSD1 Both digitally managed	TW & TSD1 Both digitally managed	TW & TSD1 Both digitally managed	TW digitally managed TSD1 & TSD2 Both analog managed	TW digitally managed TSD1 Analog managed

4.38 Vs compensation (duty cycle adjustment) module

All stand-alone HS outputs can be programmed to calculate some internal duty cycle adjustment to adapt the duty cycle to a changing supply voltage at Vs. This feature is aimed at avoiding LED brightness flickering in case of alternating supply voltage. The correction of the duty cycle is based on the following formula:

Equation 1 Duty cycle correction

$$DutyCycle = \frac{V_{th} - V_{led}}{V_{bat} - V_{led}} \cdot x \cdot DC_{nom}$$

V_{th} = Duty cycle reference voltage: defined as 10 V

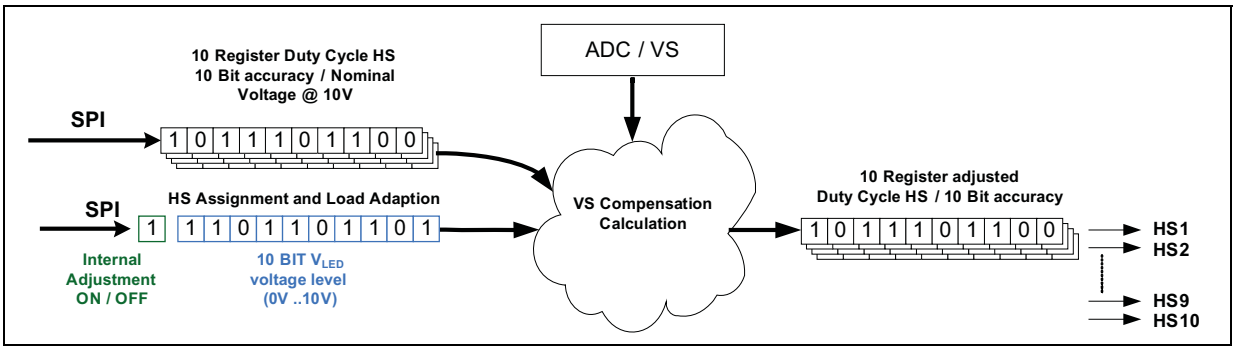
V_{bat} = Reference voltage: defined as voltage at pin VS V_{LED} = Voltage drop on the external LED

DC_{nom} = Nominal Duty Cycle programmed by SPI< PWMx DCx>

To be compatible to different LED load characteristics the value for V_{LED} can be programmed for each output by a dedicated control register OUT7_VLED … OUT15_VLED (CR 17 to CR 20). Auto compensation features can be activated for all HS outputs each by setting OUTx_AUTOCOMP_EN (CR 17 to CR 20).

The programmed LED voltage (OUTx_VLED (CR17 to CR20)) must be lower than V_{th} (10 V).

Figure 53. Block diagram Vs compensation (duty cycle adjustment) module

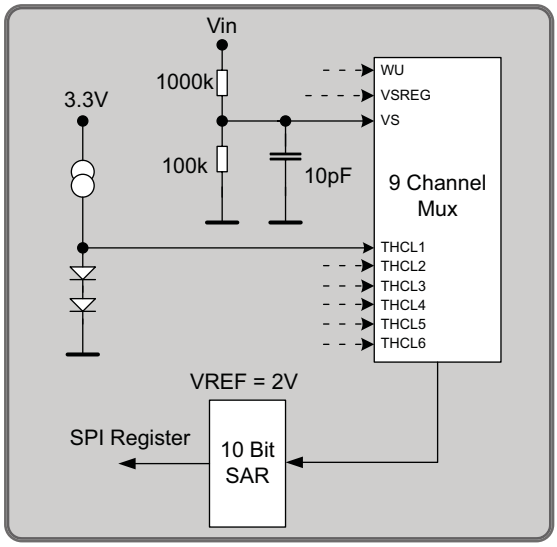


4.39 Analog digital converter

Voltage signals V_S, V_{SREG}, V_{WU} and TH_CL1...6 are read out sequentially. The voltage signals are multiplexed to an ADC. The ADC is realized as a 10 Bit SAR, sampled at f_{ADC} frequency which is obtained dividing by 4 the main clock f_{clk2}.

Each channel will be converted with a conversion time t_{con}, therefore an update of the ADC value is available every t_{con} * 9. In case of WU is directly connected to $V_{Protected}$ (refer to *Figure 61*), the input must be protected by a series resistance of typical 1 kΩ to sustain reverse battery condition.

Figure 54. Sequential ADC Read Out for VSREG, VS, WU and THCL1... THCL6



Note: As best practice, in order to release valid temperature or voltage information, it is strongly recommended to filter out sequential reading of a relevant channel (i.e. reading from 3 to 5 ADC conversions, excluding a potential outlier, and then weight the remaining data).

5 Serial Peripheral Interface (SPI)

A 32-bit SPI is used for bi-directional communication with the microcontroller.

The SPI is driven by a microcontroller with its SPI peripheral running in the following mode: CPOL = 0 and CPHA = 0.

For this mode input data is sampled by the low to high transition of the clock CLK, and output data is changed from the high to low transition of CLK. This device is not limited to microcontroller with a built-in SPI. Only three CMOS-compatible output Pins and one input Pin will be needed to communicate with the device. A fault condition can be detected by setting CSN to low. If CSN = 0, the DO-Pin will reflect the global error flag (fault condition) of the device.

- Chip Select Not (CSN)
  The input Pin is used to select the serial interface of this device. When CSN is high, the output Pin (DO) is in high impedance state. A low signal activates the output driver and a serial communication can be started. The state during CSN = 0 is called a communication frame. If CSN = low for t > $t_{CSNfail}$ the DO output will be switched to high impedance in order not to block the signal line for other SPI nodes.
- Serial Data In (DI)
  The input Pin is used to transfer data serial into the device. The data applied to the DI will be sampled at the rising edge of the CLK signal and shifted into an internal 32-bit shift register. At the rising edge of the CSN signal the content of the shift register will be transferred to Data Input Register. The writing to the selected Data Input Register is only enabled if exactly 32 bits are transmitted within one communication frame (i.e. CSN low). If more or less clock pulses are counted within one frame the complete frame will be ignored. This safety function is implemented to avoid an activation of the output stages by a wrong communication frame.

Note: Due to this safety functionality a daisy chaining of SPI is not possible. Instead, a parallel operation of the SPI bus by controlling the CSN signal of the connected IC's is recommended.

- Serial Data Out (DO)
  The data output driver is activated by a logical low level at the CSN input and will go from high impedance to a low or high level depending on the global error flag (fault condition). The first rising edge of the CLK input after a high to low transition of the CSN Pin will transfer the content of the selected status register into the data out shift register. Each subsequent falling edge of the CLK will shift the next bit out.
- Serial Clock (CLK)
  The CLK input is used to synchronize the input and output serial bit streams. The data input (DI) is sampled at the rising edge of the CLK and the data output (DO) will change with the falling edge of the CLK signal. The SPI can be driven with a CLK frequency up to 4 MHz.

5.1 ST SPI 4.0

The ST-SPI is a standard used in ST Automotive ASSP devices.

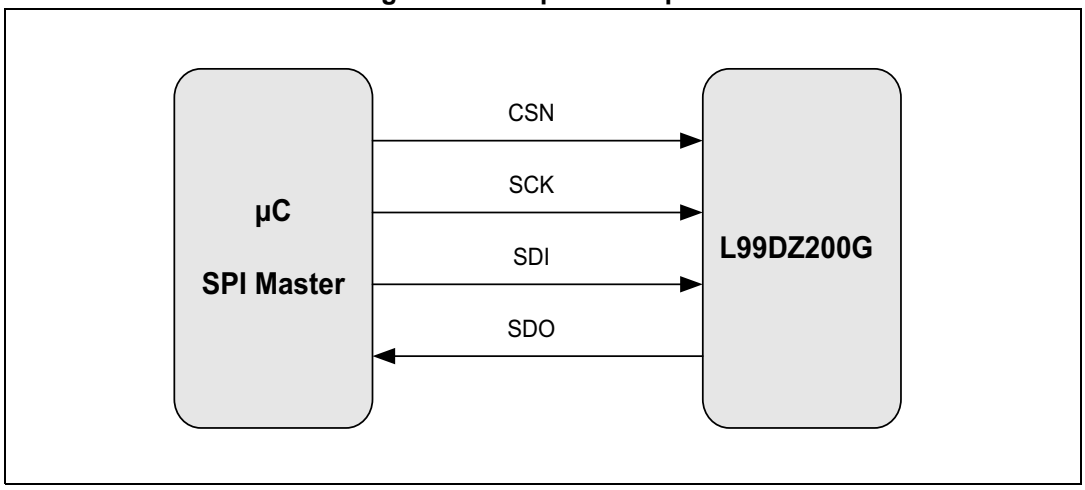
This chapter describes the SPI protocol standardization. It defines a common structure of the communication frames and defines specific addresses for product and status information.

The ST-SPI allows the use of generic software to operate the devices while maintaining the required flexibility to adapt it to the individual functionality of a particular product. In addition, failsafe mechanisms are implemented to protect the communication from external influences and wrong or unwanted usage.

The devices Serial Peripheral Interface are compliant to the ST SPI Standard Rev. 4.0.

5.1.1 Physical Layer

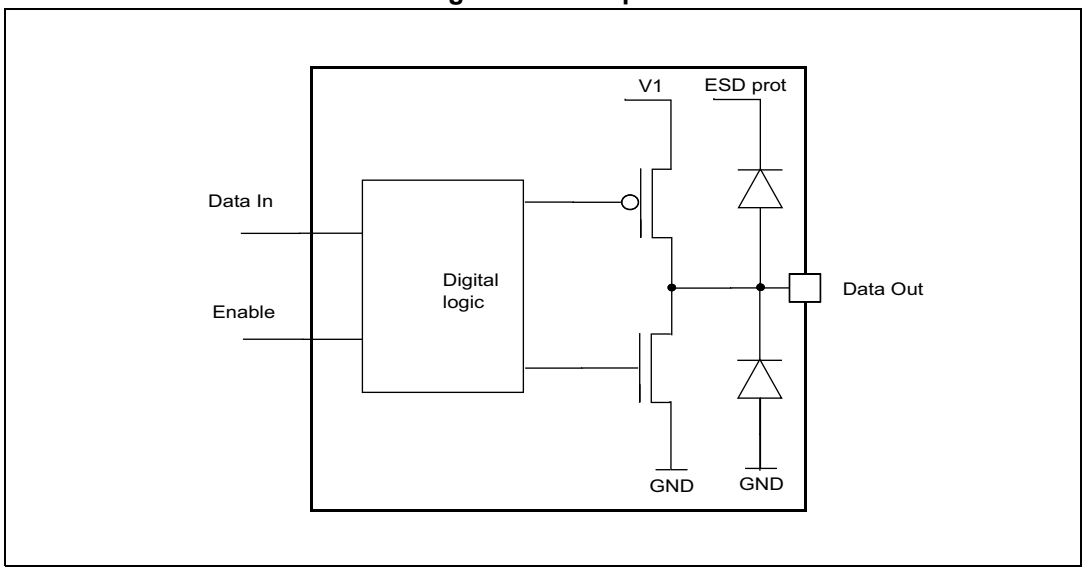
Figure 55. SPI pin description



5.2 Signal description

- Chip Select Not (CSN)
  The communication interface is de-selected, when this input signal is logically high. A falling edge on CSN enables and starts the communication while a rising edge finishes the communication and the sent command is executed when a valid frame was sent. During communication start and stop the Serial Clock (SCK) has to be logically low. The Serial Data Out (SDO) is in high impedance when CSN is high or a communication timeout was detected.
- Serial Clock (SCK)
  This SCK provides the clock of the SPI. Data present at Serial Data Input (SDI) is latched on the rising edge of Serial Clock (SCK) into the internal shift registers while on the falling edge data from the internal shift registers are shifted out to Serial Data Out (SDO).
- Serial Data Input (SDI)
  This input is used to transfer data serially into the device. Data is latched on the rising edge of Serial Clock (SCK).
- Serial Data Output (SDO)
  This output signal is used to transfer data serially out of the device. Data is shifted out on the falling edge of Serial Clock (SCK).

Figure 56. SDO pin

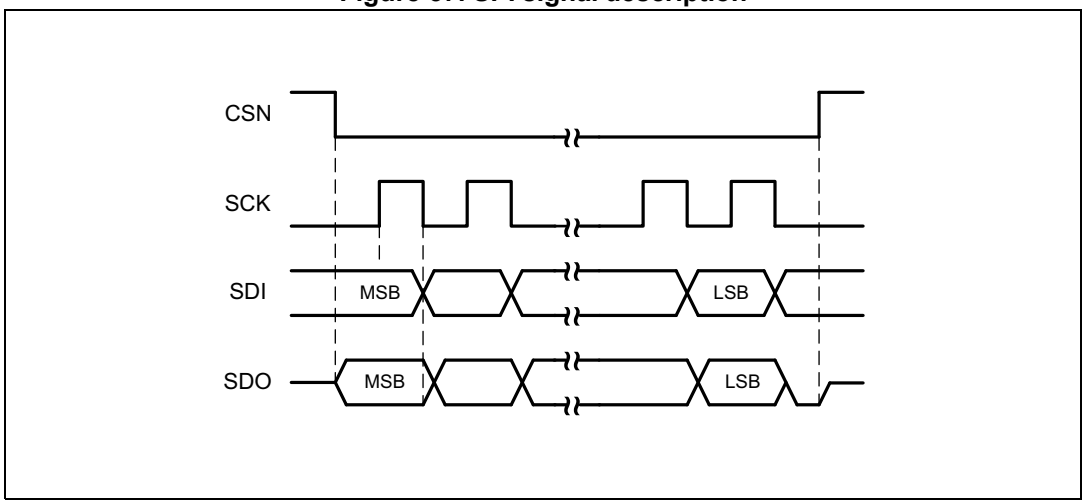


5.2.1 Clock and data characteristics

The ST-SPI can be driven by a microcontroller with its SPI peripheral running in the following mode:

CPOL = 0
CPHA = 0

Figure 57. SPI signal description



The communication frame starts with the falling edge of the CSN (Communication Start). SCK has to be low.

The SDI data is then latched at all the subsequent rising SCK edges into the internal shift registers. After Communication Start the SDO will leave 3-state mode and present the MSB of the data shifted out to SDO. At the subsequent SCK falling edges, data are shifted out to SDO through the internal shift registers. The communication frame is finished with the rising edge of CSN. If a valid communication took place (e.g. correct number of SCK cycles,

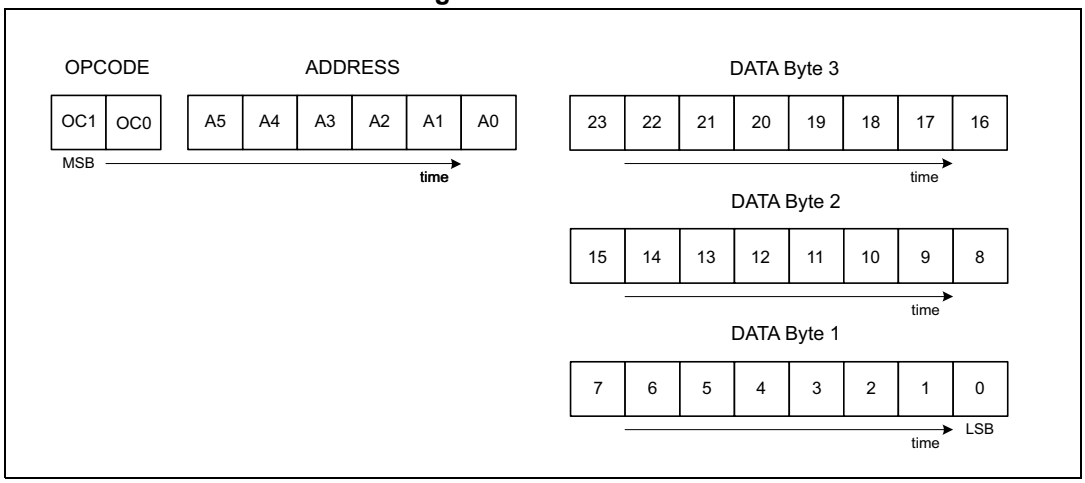
access to a valid address), the requested operation according to the Operating Code will be performed (Write or Clear operation).

5.2.2 Communication Protocol

SDI Frame

The devices Data-In Frame consist of 32-bit (OpCode (2 bits) + Address (6 bits) + Data Byte 3 + Data Byte 2 + Data Byte 1). The first two transmitted bits (MSB, MSB-1) contain the Operation Code which represents the instruction which will be performed. The following 6 bits (MSB-2 to MSB-7) represent the address on which the operation will be performed. The subsequent bytes contain the payload.

Figure 58. SDI Frame



Operating Code

The operating code is used to distinguish between different access modes to the registers of the slave device.

Table 75. Operating Codes

OC1	OC0	Description
0	0	Write Operation
0	1	Read Operation
1	0	Read & Clear Operation
1	1	Read Device Information

A **Write Operation** will lead to a modification of the addressed data by the payload if a write access is allowed (e.g. Control Register, valid data). Beside this a shift out of the content (data present at Communication Start) of the registers is performed.

A **Read Operation** shifts out the data present in the addressed register at Communication Start. The payload data will be ignored and internal data will not be modified. In addition a Burst Read can be performed.

A **Read & Clear** Operation will lead to a clear of addressed status bits. The bits to be cleared are defined first by address, secondly by payload bits set to ‘1’. Beside this a shift out of the content (data present at Communication Start) of the registers is performed.

Note: Status registers that change status during communication could be cleared by the actual Read & Clear Operation and are neither reported in actual communication nor in the following communications. To avoid a loss of any reported status it is recommended just clear status registers which are already reported in the previous communication (Selective Bitwise Clear).

Advanced Operation Codes

To provide beside the separate write of all control registers and the bitwise clear of all status registers, two Advanced Operation Codes can be used to set all control registers to the default value and to clear all status registers. A ‘set all control registers to default’ command is performed when an OpCode ‘11’ at address b’111111 is performed.

Note: Please consider that potential device specific write protected registers cannot be cleared with this command as a device Power-on-Reset is needed.

A ‘clear all status registers’ command is performed when an OpCode ‘10’ at address b’111111 is performed.

Data-In Payload

The Payload (Data Byte 1 to Data Byte 3) is the data transferred to the devices with every SPI communication. The Payload always follows the OpCode and the Address bits. For Write access the Payload represents the new data written to the addressed register. For Read & Clear operations the Payload defines which bits of the addressed Status Register will be cleared. In case of a ‘1’ at the corresponding bit position the bit will be cleared.

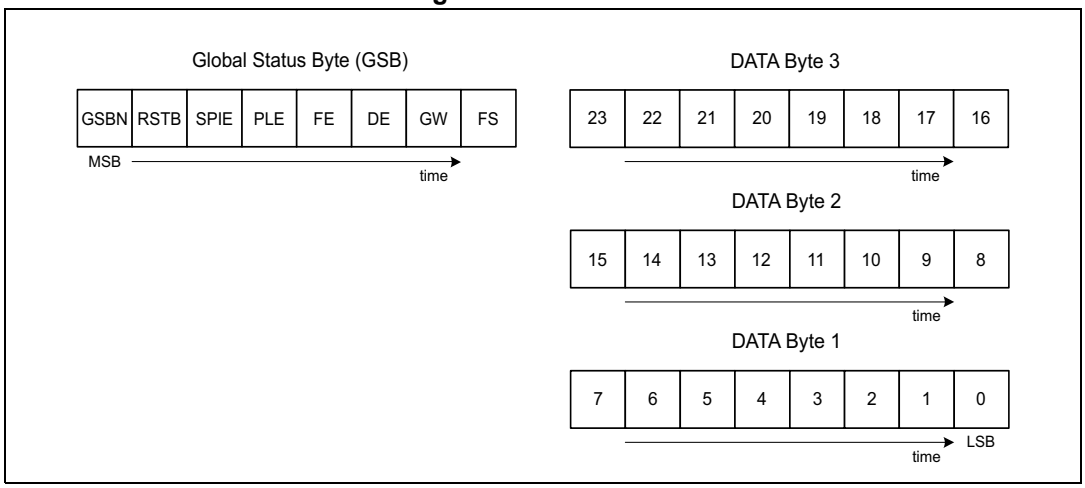
For a Read Operation the Payload is not used. For functional safety reasons it is recommended to set unused Payload to ‘0’.

SDO Frame

The data-out frame consists of 32-bits (GSB + Data Byte 1 to 3).

The first eight transmitted bits contain device related status information and are latched into the shift register at the time of the Communication Start. These 8-bits are transmitted at every SPI transaction. The subsequent bytes contain the payload data and are latched into the shift register with the eighth positive SCK edge. This could lead to an inconsistency of data between the GSB and Payload due to different shift register load times. Anyhow, no unwanted Status Register clear should appear, as status information should just be cleared with a dedicated bit clear after.

Figure 59. SDO frame



Global Status Byte (GSB)

The bits (Bit0 to Bit4) represent a logical OR combination of bits located in the Status Registers. Therefore no direct Read & Clear can be performed on these bits inside the GSB.

Table 76. Global Status Byte

Bit 31	Bit 30	Bit 29	Bit 28	Bit 27	Bit 26	Bit 25	Bit 24
GSBN	RSTB	SPIE	PLE	FE	DE	GW	FS

Global Status Bit Not (GSBN)

The GSBN is a logically NOR combination of Bit 24 to Bit 30. This bit can also be used as Global Status Flag without starting a complete communication frame as it is present directly after pulling CSN low.

Reset Bit (RSTB)

The RSTB indicates a device reset. In case this bit is set, specific internal Control Registers are set to default and kept in that state until the bit is cleared. The RSTB bit is cleared after a Read & Clear of all the specific bits in the Status Registers which caused the reset event.

SPI Error (SPIE)

The SPIE is a logical OR combination of errors related to a wrong SPI communication.

Physical Layer Error (PLE)

The PLE is a logical OR combination of errors related to the LIN and HS CAN transceivers.

Functional Error (FE)

The FE is a logical OR combination of errors coming from functional blocks (e.g. High-side overcurrent).

Device Error (DE)

The DE is a logical OR combination of errors related to device specific blocks (e.g. VS overvoltage, overtemperature).

Global Warning (GW)

The GW is a logical OR combination of warning flags (e.g. thermal warning).

Fail Safe (FS)

The FS bit indicates that the device was forced into a safe state due to mistreatment or fundamental internal errors (e.g. Watchdog failure, Voltage regulator failure).

Data-Out Payload

The Payload (Data Bytes 1 to 3) is the data transferred from the slave device with every SPI communication to the master device. The Payload always follows the OpCode and the address bits of the actual shifted in data (In-frame-Response).

5.2.3 Address Definition

Table 77. Device application access

Operating Code	
OC1	**OC0**
0	0
0	1
1	0

Table 78. Device information read access

Operating Code	
OC1	**OC0**
1	1

Table 79. RAM address range

RAM Address	Description	Access
3FH	Configuration Register	R/W
3CH	Status Register 12	R/C
…	…	
32H	Status Register 2	R/C
31H	Status Register 1	R/C
…	…	

Table 79. RAM address range (continued)

RAM Address	Description	Access
22H	Control Register 34	R/W
1DH	Control Register 29	R/W
…	…	
02H	Control Register 2	R/W

Table 80. ROM address range

ROM Address	Description	Access
3FH	<Advanced Op.>	W
3EH	<GSB Options>	R
…		
20H	<SPI CPHA test>	R
16H	<WD bit pos. 4>	R
15H	<WD bit pos. 3>	R
14H	<WD bit pos. 2>	R
13H	<WD bit pos. 1>	R
12H	<WD Type 2>	R
11H	<WD Type 1>	R
10H	<SPI mode>	R
…		
0AH	<Silicon Ver.>	R
…		
06H	<Device No.5>	R
05H	<Device No.4>	R
04H	<Device No.3>	R
03H	<Device No.2>	R
02H	<Device No.1>	R
01H	<Device Family>	R
00H	<Company Code>	R

Information registers

The *Device Information Registers* can be read by using OpCode ‘11’. After shifting out the GSB the 8-bit wide payload will be transmitted. By reading *Device Information Registers* a communication width which is minimum 16-bit plus a multiple by 8 can be used. After shifting out the GSB followed by the 8-bit wide payload a series of ‘0’ is shifted out at the SDO.

Table 81. Information Registers Map

ROM Address	Description	Access		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
3FH	<Advanced Op.>										
3EH	<GSB Options>	R	→	0	0	0	0	0	0	0	0
…											
20H	<SPI CPHA test>	R	→	0	1	0	1	0	1	0	1
16H	<WD bit pos. 4>	R	→	C0H							
15H	<WD bit pos. 3>	R	→	7FH							
14H	<WD bit pos. 2>	R	→	C0H							
13H	<WD bit pos. 1>	R	→	41H							
12H	<WD Type 2>	R	→	91H							
11H	<WD Type 1>	R	→	28H							
10H	<SPI mode>	R	→	B0H							
…			→								
0AH	<Silicon Ver.>	R	→	major revision				minor revision			
…			→								
06H	<Device No.5>	R		L99DZ200G: 00H							
05H	<Device No.4>	R	→	4BH							
04H	<Device No.3>	R	→	46H							
03H	<Device No.2>	R	→	42H							
02H	<Device No.1>	R	→	55H							
01H	<Device Family>	R	→	01H							
00H	<Company Code>	R	→	00H							

Device Identification Registers

These registers represent a unique signature to identify the device and silicon version.

<Company Code>: 00H (STMicroelectronics)

<Device Family>: 01H (BCD Power Management)

<Device No. 1>: 55H

<Device No. 2>: 42H

<Device No. 3>: 46H

<Device No. 4>: 4BH

<Device No. 5>: 00H

SPI Modes

By reading out the <SPI Mode> register general information of SPI usage of the *Device Application Registers* can be read.

Table 82. SPI Mode Register

Bit	7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit	1	Bit	0
BR		DL2	DL1	DL0	0	0	S1		S0	
1		0	1	1	0	0	0		0	

<SPI Mode>: B0H (Burst Mode read available, 32 bit, no data consistency check)

SPI Burst Read

Table 83. Burst Read Bit

Bit 7	Description
0	BR not available
1	BR available

The SPI Burst Read bit indicates if a burst read operation is implemented. The intention of a Burst Read is e.g. used to perform a device internal memory dump to the SPI Master.

The start of the Burst Read is like a normal Read Operation. The difference is, that after the SPI Data Length the CSN is not pulled high and the SCK will be continuously clocked. When the normal SCK max count is reached (SPI Data Length) the consecutive addressed data will be latched into the shift register. This procedure is performed every time when the SCK payload length is reached.

In case the automatic incremented address is not used by the device, undefined data is shifted out. An automatic address overflow is implemented when address 3FH is reached. The SPI Burst Read is limited by the CSN low timeout.

SPI Data Length

The SPI Data Length value indicates the length of the SCK count monitor which is running for all accesses to the Device Application Registers. In case a communication frame with an SCK count not equal to the reported one will lead to a SPI Error, the data will be rejected.

Table 84. SPI Data Length

Bit 6	Bit 5	Bit 4	Description
DL2	DL1	DL0	
0	0	0	invalid
0	0	1	16-bit SPI
0	1	0	24-bit SPI
0	1	1	32-bit SPI
			…
1	1	1	64-bit SPI

Data Consistency Check (Parity/CRC)

Table 85. Data Consistency Check

Bit 1	Bit 0	Description
S1	S0	
0	0	not used
0	1	Parity used
1	0	CRC used
1	1	Invalid

Watchdog Definition

In case a watchdog is implemented the default settings can be read out via the *Device Information Registers*.

Table 86. WD Type/Timing

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	WD1	WD0						
<WD Type 1/2>	0	0	Register is not used					
<WD Type 1>	0	1	WT5	WT4	WT3	WT2	WT1	WT0
		1	1	0	1	0	0	0
			Watchdog Timeout / Long Open Window WT[5:0] * 5ms					
<WD Type 2>	1	0	OW2	OW1	OW0	CW2	CW1	CW0
	1	0	0	1	0	0	0	1
			Open Window OW[2:0] * 5ms			Closed Window CW[2:0] * 5ms		
<WD Type 1/2>	1	1	Invalid					

<*WD Type 1*>: 28H (Long Open Window: 200 ms)

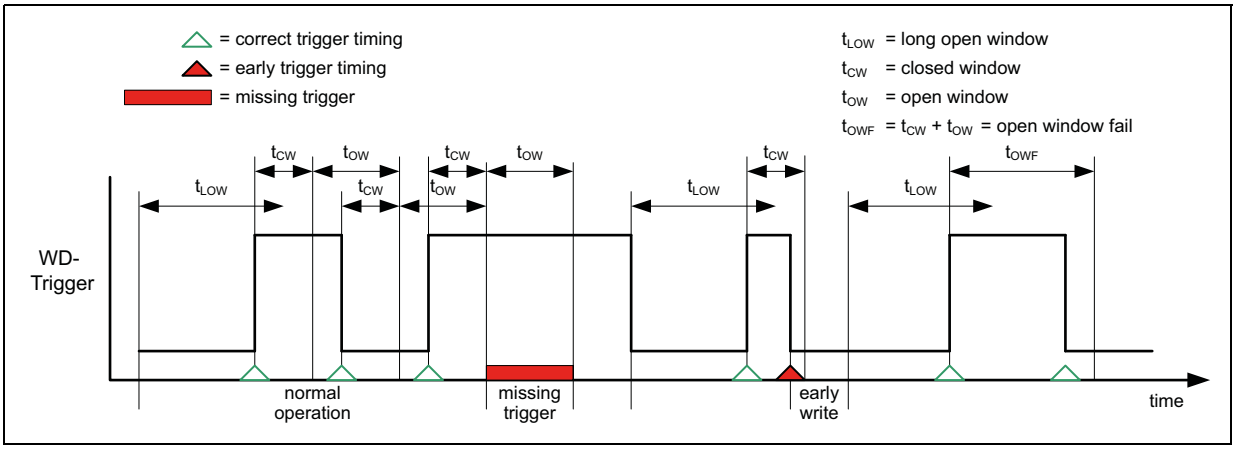
<*WD Type 2*>: 91H (Open Window. 10 ms, Closed Window: 5 ms)

<WD Type 1> indicates the Long Open Window (timeout) which is opened at the start of the watchdog. The binary value of WT[5:0] times 5 ms indicates the typical value of the Timeout Time.

<WD Type 2> describes the default timing of the window watchdog.

The binary value of CW[2:0] times 5 ms defines the typical Closed Window time and OW[2:0] times 5 ms defines the typical Open Window time.

Figure 60. Window watchdog operation



The watchdog trigger bit location is defined by the <WD bit pos. X> registers.

Table 87. WD bit position

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	WB1	WB0						
<WD bit pos. X>	0	0	Register is not used					
<WD bit pos. X>	0	1	WBA5	WBA4	WBA3	WBA2	WBA1	WBA0
<WD bit pos. 1>	0	1	0	0	0	0	0	1
<WD bit pos. 3>	0	1	1	1	1	1	1	1
			Defines the register addresses of the WD trigger bits					
<WD bit pos. X>	1	0	WBA5	WBA4	WBA3	WBA2	WBA1	WBA0
			Defines the stop address of the address range (previous <WD bit pos. X> is a WB = '01'). The consecutive <WD bit pos. X> has to be a WB = '11'					
<WD bit pos. X>	1	1	0	WBP 4	WBP3	WBP2	WBP1	WBP0
<WD bit pos. 2>	1	1	0	0	0	0	0	0
<WD bit pos. 4>	1	1	0	0	0	0	0	0
			Defines the binary bit position of the WD trigger bit within the register					

<*WD bit pos 1*>: 41H; watchdog trigger bit located at address 01H (*CR1*)

<*WD bit pos 2*>: C0H; watchdog trigger bit location is bit0

<*WD bit pos 3*>: 7FH; watchdog trigger bit located at address 3FH (Config Register)

<*WD bit pos 4*>: C0H; watchdog trigger bit location is bit0

Device Application Registers (RAM)

The *Device Application Registers* are all registers accessible using OpCode '00', '01' and '10'. The functions of these registers are defined in the device specification.

5.2.4 Protocol Failure Detection

To realize a protocol which covers certain failsafe requirements a basic set of failure detection mechanisms are implemented.

Clock monitor

During communication (CSN low to high phase) a clock monitor counts the valid SCK clock edges. If the SCK edges do not correlate with the SPI Data Length an SPIE is reported with the next command and the actual communication is rejected.

By accessing the Device Information Registers (OpCode = '11') the Clock Monitor is set to a minimum of 16 SCK edges plus a multiple by 8 (e.g. 16, 25, 32 …). Providing no SCK edge during a CSN low to high phase is not recognized as an SPIE. For a SPI Burst Read also the SPI Data Length plus multiple numbers of Payloads SCK edges are assumed as a valid communication.

SCK Polarity (CPOL) check

To detect the wrong polarity access via SCK the internal Clock monitor is used. Providing first a negative edge on SCK during communication (CSN low to high phase) or a positive edge at last will lead to an SPI Error reported in the next communication and the actual data is rejected.

SCK Phase (CPHA) check

To verify, that the SCK Phase of the SPI master is set correctly a special Device Information Register is implemented. By reading this register the data must be 55H. In case AAH is read the CPHA setting of the SPI master is wrong and a proper communication cannot be guaranteed.

CSN timeout

By pulling CSN low the SDO is set active and leaves its 3-state condition. To ensure communication between other SPI devices within the same bus even in case of CSN stuck at low a CSN timeout is implemented. By pulling CSN low an internal timer is started. After timer end is reached the actual communication is rejected and the SDO is set to 3-state condition.

SDI stuck at GND

As a communication with data all-'0' and OpCode '00' on address b'000000 cannot be distinguished between a valid command and a SDI stuck at GND this communication is not

allowed. Nevertheless, in case a stuck at GND is detected the communication will be rejected and the SPIE will be set with the next communication.

SDI stuck at HIGH

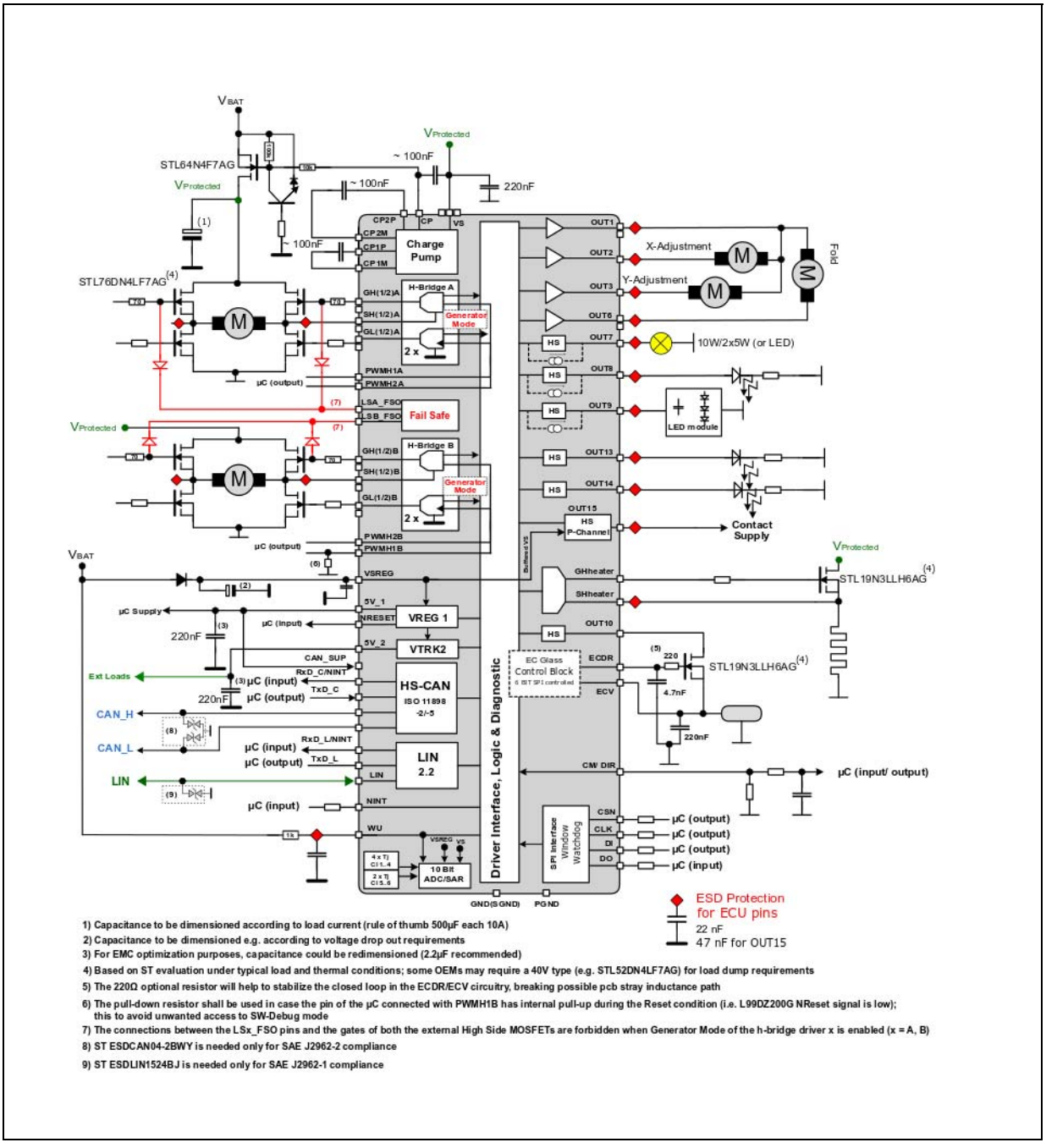
As a communication with data all-‘1’ and OpCode ‘11’ on address b’111111 cannot be distinguished between a valid command and a SDI stuck at HIGH this communication is not allowed. In case a stuck at HIGH is detected the communication will be rejected and the SPIE will be set with the next communication.

SDO stuck @

The SDO stuck at GND and stuck at HIGH has to be detected by the SPI master. As the definition of the GSB guarantees at least one toggle, a GSB with all-‘0’ or all –‘1’ reports a stuck at error.

6 Application

Figure 61. Typical application diagram



1) Capacitance to be dimensioned according to load current (rule of thumb 500µF each 10A)
2) Capacitance to be dimensioned e.g. according to voltage drop out requirements
3) For EMC optimization purposes, capacitance could be redimensioned (2.2µF recommended)
4) Based on ST evaluation under typical load and thermal conditions; some OEMs may require a 40V type (e.g. STL52DN4LF7AG) for load dump requirements
5) The 220Ω optional resistor will help to stabilize the closed loop in the ECDR/ECV circuitry, breaking possible pcb stray inductance path
6) The pull-down resistor shall be used in case the pin of the µC connected with PWMH1B has internal pull-up during the Reset condition (i.e. L99DZ200G NReset signal is low); this to avoid unwanted access to SW-Debug mode
7) The connections between the LSx_FSO pins and the gates of both the external High Side MOSFETs are forbidden when Generator Mode of the h-bridge driver x is enabled (x = A, B)
8) ST ESDCAN04-2BWY is needed only for SAE J2962-2 compliance
9) ST ESDLIN1524BJ is needed only for SAE J2962-1 compliance

7 SPI registers

7.1 Global Status Byte GSB

Table 88. Global Status Byte (GSB)

Global Status Byte GSB							
Bit 31	**Bit 30**	**Bit 29**	**Bit 28**	**Bit 27**	**Bit 26**	**Bit 25**	**Bit 24**
1 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
GSBN	RSTB	SPIE	PLE	FE	DE	GW	FS
Global Status Bit Inverted	Reset	SPI Error	Physical Layer Error (CAN,LIN)	Functional Error	Device Error	Global Warning	Fail Safe

Table 89. Global Status Byte (GSB) description

Bit	Name	Description
31	GSBN	Global Status Bit Inverted The GSBN is a logically NOR combination of GSB Bits 24 to Bit 30(1). This bit can also be used as Global Status Flag without starting a complete communication frame as it is present at SDO directly after pulling CSN low. 0: error detected (1 or several GSB bits from 24 to 30 are set) 1: no error detected (default after Power-on) Specific failures may be masked in the Configuration Register 0x3F. A masked failure will still be reported in the GSB by the related failure flag, however it is not reflected in the GSBN (bit 31).
30	RSTB	Reset The RSTB indicates a device reset and it is set in case of the following events: – VPOR (SR1 - 0x31) – WDFAIL (SR1 - 0x31) – V1UV (SR1 - 0x31) – FORCED_SLEEP_TSD2/V1SC (SR1 - 0x31) 0: no reset signal has been generated (default) 1: Reset signal has been generated RSTB is cleared by a *Read & Clear* command to all bits in *Status Register 1* causing the Reset event.
29	SPIE(2)	SPI Error Bit The SPIE indicates errors related to a wrong SPI communication. – SPI_INV_CMD (SR2 - 0x32) – SPI_SCK_CNT (SR2 - 0x32) The bit is also set in case of an SPI CSN Time-out detection 0: no error (default) 1: error detected SPIE is cleared by a valid SPI command.

Table 89. Global Status Byte (GSB) description (continued)

Bit	Name	Description
28	PLE(2)	Physical Layer Error The PLE is a logical OR combination of errors related to the LIN and CAN transceivers. – LIN_PERM_DOM (SR2 - 0x32) – LIN_TXD_DOM (SR2 - 0x32) – LIN_PERM_REC (SR2 - 0x32) – CAN_RXD_REC (SR2 - 0x32) – CAN_PERM_REC (SR2 - 0x32) – CAN_PERM_DOM (SR2 - 0x32) – CAN_TXD_DOM (SR2 - 0x32) – SYSERR (SR12 - 0x3C) – FDERR (SR12 - 0x3C) 0: no error (default) 1: error detected PLE is cleared by a Read & Clear command to all related bits in Status Registers 2 and 12.
27	FE	Functional Error Bit The FE is a logical OR combination of errors coming from functional blocks. – V2SC (SR2 - 0x32) – DSMON_HSx_y (x = 1, 2 and y = A, B) (SR2 - 0x32 and SR3 – 0x33) – DSMON_LSx_y (x = 1, 2 and y = A, B) (SR2 - 0x32 and SR3 – 0x33) – OUTx_HS_OC_TH_EX (x = 1, 2, 3, 6) (SR3 - 0x33) – OUTx_LS_OC_TH_EX (x = 1, 2, 3, 6) (SR3 - 0x33) – OUTx_OC_TH_EX (x = 7, 8, 15) (SR3 - 0x33) – OUTx_OC_STAT (x = 9, 10, 13, 14) (SR3 - 0x33) – LSy_FSO_OC (y= a, b) (SR3 - 0x33) – OUTx_HS_SHORT (x = 1, 2, 3, 6) (SR4 - 0x34)(3) – OUTx_LS_SHORT (x = 1, 2, 3, 6) (SR4 - 0x34)(3) – ECV_OC (SR5 - 0x35) – DSMON_HEAT (SR5 - 0x35) – OUTx_HS_OL (x = 1, 2, 3, 6) (SR5 - 0x35)(4) – OUTx_LS_OL (x = 1, 2, 3, 6) (SR5 - 0x35) – OUTx_OL_STAT (x = 7, 8, 9,10, 13, 14, 15) (SR5 - 0x35) – GH_OL (SR5 - 0x35) – ECV_OL (SR5 - 0x35) 0: no error (default) 1: error detected FE is cleared by a Read & Clear command to all related bits in Status Registers 2, 3, 4, 5

Table 89. Global Status Byte (GSB) description (continued)

Bit	Name	Description
26	DE	Device Error Bit DE is a logical OR combination of global errors related to the device. – VS_OV (SR2 - 0x32) – VS_UV (SR2 - 0x32) – VSREG_OV (SR2 - 0x32) – VSREG_UV (SR2 - 0x32) – CP_LOW (SR2 - 0x32) – TSD1_CLx (SR6 - 0x36) 0: no error (default) 1: error detected DE is cleared by a Read & Clear command to all related bits in Status Registers 2 and 6
25	GW(2)	Global Warning Bit GW is a logical OR combination of warning flags. Warning bits do not lead to any device state change or switch off of functions. – VSREG_EW (SR2 - 0x32) – V1_FAIL (SR2 - 0x32) – V2_FAIL (SR2 - 0x32) – CAN_SUP_LOW (SR2 - 0x32) – TW (3) (SR2 - 0x32) – SPI_INV_CMD (SR2 - 0x32) – SPI_SCK_CNT (SR2 - 0x32) 0: no error (default) 1: error detected GW is cleared by a Read & Clear command to all related bits in Status Register 2.
24	FS	Fail Safe The FS bit indicates the device was forced into a safe state due to the following failure conditions: – WDFAIL (SR1 - 0x31) – V1UV (SR1 - 0x31) – TSD2 (SR1 - 0x31) – FORCED_SLEEP_TSD/V1SC (SR1 - 0x31) or SGND_LOSS (SR1 – 0x31) All Control Registers are set to default Control Registers are blocked for WRITE access except the following bits: – TRIG (CR1 - 0x01) – V2_0 (CR1 - 0x01) – V2_1 (CR1 - 0x01) – GoTRXRDY (CR1 - 0x01) – Timer settings (bits 8…23) (CR2 - 0x02) – OUT15_x (bits 0…3) (CR6 - 0x06) – CR12 (0x0C) to CR17 (0x11); PWM frequency and duty cycles 0: Fail Safe inactive (default) 1: Fail Safe active FS is cleared upon exit from Fail-Safe mode (refer to chapter ‘Fail-Safe mode’)

1. Individual failure flags may be masked in the Configuration Register (0x3F).
2. Bit may be masked in the Configuration Register (0x3F), i.e. the bit will not be included in the Global Status Bit (GSB).

3. The detection of this error does not set the GSBN.
4. Open load status flags may be masked in the Configuration register (0x3F), i.e. the open load flag will be included in the FE flag, but will not set the GSB. TW failure status flags may be masked in the Configuration register (0x3F), i.e. the TW flag will be included in the GW flag, but will not set the GSB.

7.2 Control register overview

Table 90. Control register overview

Bit			31	30	29	28	27	26	25	24	Mode
Global Status			GSBN	RSTB	SPIE	PLE	FE	DE	GW	FS	R
Control Register											
Addr.		bits	23	22	21	20	19	18	17	16	
			15	14	13	12	11	10	9	8	
			7	6	5	4	3	2	1	0	
0x00		MSB	Reserved								
			Reserved								
		LSB	Reserved								
0x01	CR1	MSB	RES	WU_EN	RES	WU_PU	RES	RES	WU_FILT_1	WU_FILT_0	R/W
			TIMER_NINT_WAKE_SEL	TIMER_NINT_EN	LIN_WU_EN	CAN_WU_EN	CANTO_IRQ_EN	CAN_RXEN	CAN_TXEN	CAN_GO_TRX_RDY	
		LSB	HENA	HENB	V2_1	V2_0	PARITY	STBY_SEL	GO_STBY	TRIG	
0x02	CR2	MSB	T1_RESTART	T1_DIR	T1_ON_2	T1_ON_1	T1_ON_0	T1_PER_2	T1_PER_1	T1_PER_0	R/W
			T2_RESTART	T2_DIR	T2_ON_2	T2_ON_1	T2_ON_0	T2_PER_2	T2_PER_1	T2_PER_0	
		LSB	LIN_REC_ONLY	LIN_TXD_TOUT_EN	CAN_LOOP_EN	PNW_EN	V1_RESET_1	V1_RESET_0	WD_TIME_1	WD_TIME_0	
0x03	CR3	MSB	VSREG_LOCK_EN	VS_LOCK_EN	VSREG_OV_SD_EN	VSREG_UV_SD_EN	VS_OV_SD_EN	VS_UV_SD_EN	RES	RES	R/W
			RES	RES	RES	RES	RES	RES	VSREG_EWTH_9	VSREG_EWTH_8	
		LSB	VSREG_EWTH_7	VSREG_EWTH_6	VSREG_EWTH_5	VSREG_EWTH_4	VSREG_EWTH_3	VSREG_EWTH_2	VSREG_EWTH_1	VSREG_EWTH_0	

Table 90. Control register overview (continued)

0x04	CR4	MSB	RES	RES	OUT1_HS	OUT1_LS	RES	RES	OUT2_HS	OUT2_LS	R/W
			RES	RES	OUT3_HS	OUT3_LS	RES	RES	RES	RES	
		LSB	RES	RES	RES	RES	RES	RES	OUT6_HS	OUT6_LS	
0x05	CR5	MSB	OUT7_3	OUT7_2	OUT7_1	OUT7_0	OUT8_3	OUT8_2	OUT8_1	OUT8_0	R/W
			RES	RES	RES	RES	OUT10_3	OUT10_2	OUT10_1	OUT10_0	
		LSB	RES	RES	RES	GH	RES	RES	RES	RES	
0x06	CR6	MSB	OUT9_3	OUT9_2	OUT9_1	OUT9_0	OUT13_3	OUT13_2	OUT13_1	OUT13_0	R/W
			OUT14_3	OUT14_2	OUT14_1	OUT14_0	OUT15_3	OUT15_2	OUT15_1	OUT15_0	
		LSB	RES	RES	RES	RES	RES	RES	RES	RES	
0x07	CR7	MSB	OUT1_OCR	OUT2_OCR	OUT3_OCR	OUT6_OCR	OUT7_OCR	OUT8_OCR	OUT15_OCR	RES	R/W
			RES	RES	RES	OUT1_SHORT_DIS	OUT2_SHORT_DIS	OUT3_SHORT_DIS	OUT6_SHORT_DIS	RES	
		LSB	RES	RES	CM_DIR_CONF_1	CM_DIR_CONF_0	CM_SEL_3	CM_SEL_2	CM_SEL_1	CM_SEL_0	
0x08	CR8	MSB	OUT1_OCR_THX_EN	OUT2_OCR_THX_EN	OUT3_OCR_THX_EN	OUT6_OCR_THX_EN	OUT7_OCR_THX_EN	OUT8_OCR_THX_EN	OUT15_OCR_THX_EN	RES	R/W
			OUT7_OCR_TON_1	OUT7_OCR_TON_0	OUT8_OCR_TON_1	OUT8_OCR_TON_0	OUT15_OCR_TON_1	OUT15_OCR_TON_0	OUTHB_OCR_TON_1	OUTHB_OCR_TON_0	
		LSB	OUT7_OCR_FREQ_1	OUT7_OCR_FREQ_0	OUT8_OCR_FREQ_1	OUT8_OCR_FREQ_0	OUT15_OCR_FREQ_1	OUT15_OCR_FREQ_0	OUTHB_OCR_FREQ_1	OUTHB_OCR_FREQ_0	
0x09	CR9	MSB	OUT8_RDSON	OUT7_RDSON	OUT1_6_RDSON	OUT9_CCM_EN	OUT8_CCM_EN	OUT7_CCM_EN	RES	RES	R/W
			RES	OUT15_OL	OUT14_OL	OUT13_OL	RES	RES	OUT10_OL	OUT9_OL	
		LSB	RES	OUT15_OC	OUT14_OC	OUT13_OC	RES	RES	OUT10_OC	OUT9_OC	
0x0A	CR10	MSB	DIAG_2_A	DIAG_1_A	DIAG_0_A	DIRHA	SD2B	SDS2B	SD1B	SDS1B	R/W
			SD2A	SDS2A	SD1A	SDS1A	COPT_3_A	COPT_2_A	COPT_1_A	COPT_0_A	
		LSB	H_OLTH_HIGH_A	OL_H1L2_A	OL_H2L1_A	SLEW_4_A	SLEW_3_A	SLEW_2_A	SLEW_1_A	SLEW_0_A	

Table 90. Control register overview (continued)

0x0B	CR11	MSB	RES	RES	RES	RES	RES	RES	GH_OL_EN	GH_TH_2	R/W
			GH_TH_1	GH_TH_0	ECV_LS	ECV_OCR	RES	RES	RES	ECON	
		LSB	RES	RES	EC_5	EC_4	EC_3	EC_2	EC_1	EC_0	
0x0C	CR12	MSB	PMW1_FREQ_1	PMW1_FREQ_0	PMW2_FREQ_1	PMW2_FREQ_0	PMW3_FREQ_1	PMW3_FREQ_0	PMW4_FREQ_1	PMW4_FREQ_0	R/W
			PMW5_FREQ_1	PMW5_FREQ_0	PMW6_FREQ_1	PMW6_FREQ_0	PMW7_FREQ_1	PMW7_FREQ_0	RES	RES	
		LSB	RES	RES	RES	RES	RES	RES	RES	RES	
0x0D	CR13	MSB	RES	RES	PWM1_DC_9	PWM1_DC_8	PWM1_DC_7	PWM1_DC_6	PWM1_DC_5	PWM1_DC_4	R/W
			PWM1_DC_3	PWM1_DC_2	PWM1_DC_1	PWM1_DC_0	RES	RES	PWM2_DC_9	PWM2_DC_8	
		LSB	PWM2_DC_7	PWM2_DC_6	PWM2_DC_5	PWM2_DC_4	PWM2_DC_3	PWM2_DC_2	PWM2_DC_1	PWM2_DC_0	
0x0E	CR14	MSB	RES	RES	PWM3_DC_9	PWM3_DC_8	PWM3_DC_7	PWM3_DC_6	PWM3_DC_5	PWM3_DC_4	R/W
			PWM3_DC_3	PWM3_DC_2	PWM3_DC_1	PWM3_DC_0	RES	RES	PWM4_DC_9	PWM4_DC_8	
		LSB	PWM4_DC_7	PWM4_DC_6	PWM4_DC_5	PWM4_DC_4	PWM4_DC_3	PWM4_DC_2	PWM4_DC_1	PWM4_DC_0	
0x0F	CR15	MSB	RES	RES	PWM5_DC_9	PWM5_DC_8	PWM5_DC_7	PWM5_DC_6	PWM5_DC_5	PWM5_DC_4	R/W
			PWM5_DC_3	PWM5_DC_2	PWM5_DC_1	PWM5_DC_0	RES	RES	PWM6_DC_9	PWM6_DC_8	
		LSB	PWM6_DC_7	PWM6_DC_6	PWM6_DC_5	PWM6_DC_4	PWM6_DC_3	PWM6_DC_2	PWM6_DC_1	PWM6_DC_0	
0x10	CR16	MSB	RES	RES	PWM7_DC_9	PWM7_DC_8	PWM7_DC_7	PWM7_DC_6	PWM7_DC_5	PWM7_DC_4	R/W
			PWM7_DC_3	PWM7_DC_2	PWM7_DC_1	PWM7_DC_0	RES	RES	RES	RES	
		LSB	RES	RES	RES	RES	RES	RES	RES	RES	
0x11	CR17	MSB	RES	OUT7_AUTOCOMP_EN	OUT7_VLED_9	OUT7_VLED_8	OUT7_VLED_7	OUT7_VLED_6	OUT7_VLED_5	OUT7_VLED_4	R/W
			OUT7_VLED_3	OUT7_VLED_2	OUT7_VLED_1	OUT7_VLED_0	RES	OUT8_AUTOCOMP_EN	OUT8_VLED_9	OUT8_VLED_8	
		LSB	OUT8_VLED_7	OUT8_VLED_6	OUT8_VLED_5	OUT8_VLED_4	OUT8_VLED_3	OUT8_VLED_2	OUT8_VLED_1	OUT8_VLED_0	

Table 90. Control register overview (continued)

0x12	CR 18	MSB	RES	OUT9_AUTOCOMP_EN	OUT9_VLED_9	OUT9_VLED_8	OUT9_VLED_7	OUT9_VLED_6	OUT9_VLED_5	OUT9_VLED_4	R/W
			OUT9_VLED_3	OUT9_VLED_2	OUT9_VLED_1	OUT9_VLED_0	RES	OUT10_AUTOCOMP_EN	OUT10_VLED_9	OUT10_VLED_8	
		LSB	OUT10_VLED_7	OUT10_VLED_6	OUT10_VLED_5	OUT10_VLED_4	OUT10_VLED_3	OUT10_VLED_2	OUT10_VLED_1	OUT10_VLED_0	
0x13	CR 19	MSB	RES	OUT13_AUTOCOMP_EN	OUT13_VLED_9	OUT13_VLED_8	OUT13_VLED_7	OUT13_VLED_6	OUT13_VLED_5	OUT13_VLED_4	R/W
			OUT13_VLED_3	OUT13_VLED_2	OUT13_VLED_1	OUT13_VLED_0	RES	OUT14_AUTOCOMP_EN	OUT14_VLED_9	OUT14_VLED_8	
		LSB	OUT14_VLED_7	OUT14_VLED_6	OUT14_VLED_5	OUT14_VLED_4	OUT14_VLED_3	OUT14_VLED_2	OUT14_VLED_1	OUT14_VLED_0	
0x14	CR 20	MSB	RES	OUT15_AUTOCOMP_EN	OUT15_VLED_9	OUT15_VLED_8	OUT15_VLED_7	OUT15_VLED_6	OUT15_VLED_5	OUT15_VLED_4	R/W
			OUT15_VLED_3	OUT15_VLED_2	OUT15_VLED_1	OUT15_VLED_0	RES	RES	RES	RES	
		LSB	RES	RES	RES	RES	RES	RES	RES	RES	
0x15	CR 21	MSB	DIAG_2_B	DIAG_1_B	DIAG_0_B	DIRHB	RES	RES	RES	RES	R/W
			RES	RES	RES	RES	COPT_3_B	COPT_2_B	COPT_1_B	COPT_0_B	
		LSB	H_OLTH_HIGH_B	OL_H1L2_B	OL_H2L1_B	SLEW_4_B	SLEW_3_B	SLEW_2_B	SLEW_1_B	SLEW_0_B	
0x16	CR 22	MSB	RES	RES	RES	RES	RES	RES	RES	RES	R/W
			RES	RES	RES	RES	RES	RES	RES	RES	
		LSB	RES	RES	RES	GENERATOR_MODE_EN	DEBUG_EXIT	CP_OFF	ICMP	WD_EN	
0x3F	Conf Reg	MSB	WU_CONFIG	LIN_WU_CONFIG	LIN_HS_EN	TSD_CONFIG	ECV_HV	V2_CONFIG	ICMP_CONFIG_EN	WD_CONFIG_EN	R/W
			MASK_OL_HS1	MASK_OL_LS1	MASK_TW	MASK_EC_OL	MASK_OL	MASK_SPIE	MASK_PLE	MASK_GW	
		LSB	CP_OFF_EN	CP_LOW_CONFIG	CP_DITH_DIS	RES	FS_FORCED	RES	DMA	DMB	TRIG

7.3 Status register overview

Table 91. Status register overview

bit			31	30	29	28	27	26	25	24	Mode
Global Status			GSBN	RSTB	SPIE	PLE	FE	DE	GW	FS	R
Status Register											
Addr.		bits	23	22	21	20	19	18	17	16	
			15	14	13	12	11	10	9	8	
			7	6	5	4	3	2	1	0	
0x31	SR1	MSB	VS_OV_WAKEUP	WU_STATE	SGND_LOSS	WU_WAKE	WAKE_CAN	WAKE_LIN	WAKE_TIMER	DEBUG_ACTIVE	R
			V1UV	V1_ RESTART_2	V1_ RESTART_1	V1_ RESTART_0	WDFAIL_ CNT_3	WDFAIL_ CNT_2	WDFAIL_ CNT_1	WDFAIL_ CNT_0	
		LSB	DEVICE_ STATE_1	DEVICE_ STATE_0	TSD2	TSD1	FORCED_ SLEEP_ TSD2/V1SC	FORCED_ SLEEP_WD	WDFAIL	VPOR	
0x32	SR2	MSB	LIN_PERM_ DOM	LIN_TXD_DOM	LIN_PERM_ REC	CAN_RXD _REC	CAN_PERM _REC	CAN_PERM _DOM	CAN_TXD _DOM	CAN_SUP_LOW	R
			DSMON_HS2_A	DSMON_HS1_A	DSMON_LS2_A	DSMON_LS1_A	SPI_INV_CMD	SPI_SCK_CNT	CP_LOW	TW	
		LSB	V2SC	V2FAIL	V1FAIL	VSREG_EW	VSREG_OV	VSREG_UV	VS_OV	VS_UV	
0x33	SR3	MSB	OUT1_HS_OC_TH_EX	OUT1_LS_OC_TH_EX	OUT2_HS_OC_TH_EX	OUT2_LS_OC_TH_EX	OUT3_HS_OC_TH_EX	OUT3_LS_OC_TH_EX	OUT6_HS_OC_TH_EX	OUT6_LS_OC_TH_EX	R
			OUT7_OC_TH_EX	OUT8_OC_TH_EX	OUT9_OC_STAT	OUT10_OC_STAT	OUT13_OC_STAT	OUT14_OC_STAT	OUT15_OC_TH_EX	RES	
		LSB	RES	DSMON_HS2_B	DSMON_HS1_B	DSMON_LS2_B	DSMON_LS1_B	RES	LSB_FSO_OC	LSA_FSO_OC	
0x34	SR4	MSB	OUT1_HS_OCR_ALERT	OUT1_LS_OCR_ALERT	OUT2_HS_OCR_ALERT	OUT2_LS_OCR_ALERT	OUT3_HS_OCR_ALERT	OUT3_LS_OCR_ALERT	OUT6_HS_OCR_ALERT	OUT6_LS_OCR_ALERT	R
			OUT7_OCR_ALERT	OUT8_OCR_ALERT	OUT15_OCR_ALERT	RES	RES	RES	RES	RES	
		LSB	OUT1_HS_SHORT	OUT1_LS_SHORT	OUT2_HS_SHORT	OUT2_LS_SHORT	OUT3_HS_SHORT	OUT3_LS_SHORT	OUT6_HS_SHORT	OUT6_LS_SHORT	
0x35	SR5	MSB	OUT1_HS_OL	OUT1_LS_OL	OUT2_HS_OL	OUT2_LS_OL	OUT3_HS_OL	OUT3_LS_OL	OUT6_HS_OL	OUT6_LS_OL	R
			OUT7_OL_STAT	OUT8_OL_STAT	OUT9_OL_STAT	OUT10_OL_STAT	OUT13_OL_STAT	OUT14_OL_STAT	OUT15_OL_STAT	GH_OL	
		LSB	ECV_OL	RES	RES	RES	RES	RES	DSMON_HEAT	ECV_OC	

Table 91. Status register overview (continued)

0x36	**SR6**	**MSB**	WD_TIMER_STATE_1	WD_TIMER_STATE_0	RES	RES	RES	RES	ECV_VNR	ECV_VHI	R
			RES	RES	TW_CL6	TW_CL5	TW_CL4	TW_CL3	TW_CL2	TW_CL1	
		LSB	RES	RES	TSD1_CL6	TSD1_CL5	TSD1_CL4	TSD1_CL3	TSD1_CL2	TSD1_CL1	
0x37	**SR7**	**MSB**	RES	RES	TEMP_CL2_9	TEMP_CL2_8	TEMP_CL2_7	TEMP_CL2_6	TEMP_CL2_5	TEMP_CL2_4	R
			TEMP_CL2_3	TEMP_CL2_2	TEMP_CL2_1	TEMP_CL2_0	RES	RES	TEMP_CL1_9	TEMP_CL1_8	
		LSB	TEMP_CL1_7	TEMP_CL1_6	TEMP_CL1_5	TEMP_CL1_4	TEMP_CL1_3	TEMP_CL1_2	TEMP_CL1_1	TEMP_CL1_0	
0x38	**SR8**	**MSB**	RES	RES	TEMP_CL4_9	TEMP_CL4_8	TEMP_CL4_7	TEMP_CL4_6	TEMP_CL4_5	TEMP_CL4_4	R
			TEMP_CL4_3	TEMP_CL4_2	TEMP_CL4_1	TEMP_CL4_0	RES	RES	TEMP_CL3_9	TEMP_CL3_8	
		LSB	TEMP_CL3_7	TEMP_CL3_6	TEMP_CL3_5	TEMP_CL3_4	TEMP_CL3_3	TEMP_CL3_2	TEMP_CL3_1	TEMP_CL3_0	
0x39	**SR9**	**MSB**	RES	RES	TEMP_CL6_9	TEMP_CL6_8	TEMP_CL6_7	TEMP_CL6_6	TEMP_CL6_5	TEMP_CL6_4	R
			TEMP_CL6_3	TEMP_CL6_2	TEMP_CL6_1	TEMP_CL6_0	RES	RES	TEMP_CL5_9	TEMP_CL5_8	
		LSB	TEMP_CL5_7	TEMP_CL5_6	TEMP_CL5_5	TEMP_CL5_4	TEMP_CL5_3	TEMP_CL5_2	TEMP_CL5_1	TEMP_CL5_0	
0x3A	**SR10**		RES	RES	VSREG_9	VSREG_8	VSREG_7	VSREG_6	VSREG_5	VSREG_4	R
			VSREG_3	VSREG_2	VSREG_1	VSREG_0	RES	RES	RES	RES	
			RES	RES	RES	RES	RES	RES	RES	RES	
0x3B	**SR11**		RES	RES	VS_9	VS_8	VS_7	VS_6	VS_5	VS_4	R
			VS_3	VS_2	VS_1	VS_0	RES	RES	VWU_9	VWU_8	
			VWU_7	VWU_6	VWU_5	VWU_4	VWU_3	VWU_2	VWU_1	VWU_0	
0x3C	**SR12**		RES	RES	RES	RES	RES	RES	RES	RES	
			RES	RES	RES	RES	RES	RES	RES	RES	
			RES	RES	CAN_SILENT	RES	CANTO	WUP	RES	RES	

7.4 Control registers

7.4.1 Control Register CR1 (0x01)

Figure 62. Control Register CR1

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved	WU_EN	Reserved	WU_PU	Reserved		WU_FILT_1	WU_FILT_0	TIMER_NINT_WAKE_SE	TIMER_NINT_EN	LIN_WU_EN(1)	CAN_WU_EN(1)	CANTO_IRQ_EN	CAN_RXEN	CAN_TXEN	CAN_GO_TRX_RDY	HENA	HENB	V2_1	V2_0	PARITY	STBY_SEL	GO_STBY	TRIG
Reset	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Access	R	R/W	R	R/W	R		R/W																	

1. Either LIN or CAN must be enabled as wake-up source. Setting both bits 12 and 13 to '0' is an invalid setting; in this case, both bits, WU_EN (bit 22 in CR1) will be set to '1' (wake-up enabled; default) and the SPI Error Bit (SPIE) in the Global Status Byte will be set.

Table 92. CR1 signals description

Bit	Name	Description
23	Reserved	—
22	WU_EN	Wake-up Input 1 (WU) enable(1) 0: WU disabled 1: WU enabled (default)
21	Reserved	—
20	WU_PU	Wake-up Input1 Pull-up/down configuration: configuration of internal current source(1) 0: pull-down (default) 1: pull-up
19:18	Reserved	---
17	WU_FILT_1	Wake-up Input1 Filter configuration Bits: configuration of input filter(1) See *Table 93: Wake-up input1 filter configuration*
16	WU_FILT_0	
15	TIMER_NINT_WAKE_SEL	Select Timer for NINT / Wake: select timer for periodic interrupt in standby modes 0: Timer 2 (default) 1: Timer 1

Table 92. CR1 signals description (continued)

Bit	Name	Description
14	TIMER_NINT_EN	Timer NINT enable: enable timer interrupt in standby modes 0: timer interrupt disabled (default) 1: timer interrupt enabled V1_Standby mode: periodic NINT pulse generated by timer (NINT pulse at start of timer on-phase) VBAT_Standby mode: device wakes up after timer expiration and generates NReset
13	LIN_WU_EN(2)	LIN Wake-up enable: enable wake-up by LIN(3) 0: disabled 1: enabled (default)
12	CAN_WU_EN(2)	CAN Wake-up enable: enable wake-up by CAN(4) 0: disabled 1: enabled (default)
11	CANTO_IRQ_EN	CANTO Interrupt enable: enables interrupt signal in case of CAN timeout 0: CAN TO interrupt disabled 1: CAN TO interrupt enabled (default)
10	CAN_ RXEN	CAN transceiver configuration See *Table 94: CAN transceiver mode*
9	CAN_TXEN	
8	CAN_GO_TRX_RDY	CAN Transceiver transition into TRX READY mode. 0: CAN transceiver in TRX BIAS mode (default) 1: CAN transceiver is sent into TRX READY mode At Exit from TRX READY mode, this bit is set to '0' automatically. CAN Flash mode: CAN_GO_TRX_RDY is set to '1' automatically After power-on, this bit should be set to ’0’ and a clear command should be sent to status registers.
7	HENA	Enable H-bridge A 0: H-bridge A disabled (default) 1: H-bridge A enabled
6	HENB	Enable H-bridge B 0: H-bridge B disabled (default) 1: H-bridge B enabled Refer to chapter *H-bridge Control* for details
5	V2_1	Voltage Regulator V2 Configuration See *Table 95: Voltage regulator V2 configuration*
4	V2_0	

Table 92. CR1 signals description (continued)

Bit	Name	Description
3	PARITY	PARITY: Standby Command Parity Bit STBY SEL: Select Standby mode GO_STBY: Execute transition into Standby mode The STBY_SEL and GO_STBY bits are protected by a parity check. The bits STBY_SEL, GO_STBY and PARITY must represent an even number of '1', otherwise the command is ignored and the SPI_INV_CMD bit is set. *Table 96: Standby transition configuration* shows the valid settings. All other settings are invalid; command will be ignored and SPI_INV_CMD will be set. The GO_STBY bit is not cleared automatically after wake-up.
2	STBY_SEL	
1	GO_STBY	
0	TRIG	Watchdog Trigger Bit

1. Setting is only valid if input is configured as wake-up input in Configuration Register (0x3F).
2. Either LIN or CAN must be enabled as wake-up source. Setting both bits 12 and 13 to '0' is an invalid setting. In this case, both bits will be set to '1' (wake-up enabled; default) and the SPI Error Bit (SPIE) in the Global Status Byte will be set.
3. The wake-up behavior is configurable in the Configuration Register (0x3F).
4. Wake-up occurs at a wake –up event according to ISO 11898-5:2007.

Table 93. Wake-up input1 filter configuration

WU_FILT_1	WU_FILT_0	Description
0	0	Wake-up inputs monitored in static mode (filter time t_{WU_stat}) (default)
0	1	Wake- up inputs monitored in cyclic mode with Timer2 (filter time: t_{WU_cyc}; blanking time 80% of timer ON time)
1	0	Wake- up inputs monitored in cyclic mode with Timer1 (filter time: t_{WU_cyc}; blanking time 80% of timer ON time)
1	1	Invalid setting; command will be ignored and SPI_INV_CMD will be set

Table 94. CAN transceiver mode

CAN_RXEN	CAN_TXEN	Description
0	x	TRX Standby: Receiver disabled, Transmitter disabled
0	x	
1	0	TRX Listen: Receiver enabled, Transmitter disabled
1	1	TRX Normal(1): Receiver enabled, Transmitter enabled

1. CAN Flash mode: TRX Normal Mode functionality is configured automatically but SPI registers are not updated.

Table 95. Voltage regulator V2 configuration

V2_1	V2_0	Description
0	0	V2 OFF in all modes (default)
0	1	V2 ON in Active mode; OFF in Standby modes

Table 95. Voltage regulator V2 configuration (continued)

V2_1	V2_0	Description
1	0	V2 ON in Active and V1_Standby; OFF in VBAT_Standby mode
1	1	V2 ON in all modes(1)

1. In VBAT_Standby mode, if V1 is OFF, V2 cannot be a tracker regulator (V2_CONFIG=0 in Config Reg).

Table 96. Standby transition configuration

PARITY	STBY_SEL	GO_STBY	Description
0	1	1	Go to V1_Standby
1	0	1	Go to VBAT_Standby
0	0	0	No transition to standby
1	1	0	

7.4.2 Control Register CR2 (0x02)

Figure 63. Control Register CR2

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	T1_RESTART	T1_DIR	T1_ON_2	T1_ON_1	T1_ON_0	T1_PER_2	T1_PER_1	T1_PER_0	T2_RESTART	T2_DIR	T2_ON_2	T2_ON_1	T2_ON_0	T2_PER_2	T2_PER_1	T2_PER_0	LIN_REC_ONLY	LIN_TXD_TOUT_EN	CAN_LOOP_EN	PNW_EN	V1_RESET_1	V1_RESET_0	WD_TIME_1	WD_TIME_0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Access	R/W																							

Table 97. CR2 signals description

Bit	Name	Description
23	T1_RESTART	Timer 1 Restart: Restart of Timer 1 0: timer is running with period and on-time according to configuration (default) 1: restart of timer at CSN low to high transition; starting with ON phase(1) Bit is automatically reset with next SPI frame.
22	T1_DIR	T1_DIR: Timer 1 Direct Drive by DIR T1_ON_x: Timer 1 On-Time Bits Configuration of Timer 1 on-time, for details see *Table 98* and *Figure 64*
21	T1_ON_2	
20	T1_ON_1	
19	T1_ON_0	

Table 97. CR2 signals description (continued)

Bit	Name	Description
18	T1_PER_2	Configuration of Timer 1 Period 000: T1 (default) 001: T2 010: T3 011: T4 100: T5 101: T6 110: T7 111: T8
17	T1_PER_1	
16	T1_PER_0	
15	T2_RESTART	Timer 2 Restart: restart of timer 2 0: timer is running with period and on-time according to configuration (default) 1: restart of timer at CSN low to high transition; starting with ON phase(1) Bit is automatically reset with next SPI frame.
14	T2_DIR	T2_DIR: Timer 2 Direct Drive by DIR T2_ON_x: Timer 2 On-Time Bits Configuration of Timer 2 on-time, for details see *Table 98* and *Figure 64*
13	T2_ON_2	
12	T2_ON_1	
11	T2_ON_0	
10	T2_PER_2	Configuration of Timer 2 Period
9	T2_PER_1	000: T1 (default)
8	T2_PER_0	001: T2
		010: T3
		011: T4
		100: T5
		101: T6
		110: T7
		111: T8
7	LIN_REC_ONLY	LIN Transceiver Receive Only mode 0: LIN receive only mode disabled (default) 1: LIN receive only mode enabled
6	LIN_TXD_TOUT_EN	LIN TxD Timeout Enable 0: LIN TxD timeout detection disabled 1: LIN TxD timeout detection enabled (default)
5	CAN_LOOP_EN	CAN Loop Enable: CAN Looping of TxD_C to RxD_C 0: CAN looping disabled (default) 1: CAN looping enabled
4	PNW_EN	CAN Pretended Networking mode A WUP leads to transition into TRX Bias mode and an interrupt is generated. 0: pretended networking disabled (default) 1: pretended networking enabled This bit can only be set to '1' if CAN RXEN = 1

Table 97. CR2 signals description (continued)

Bit	Name	Description
3	V1_RESET_1	Voltage Regulator V1 Reset Threshold(2) 00: Vrt4 (default) 01: Vrt3 10: Vrt2 11: Vrt1 thresholds are monitored in Active mode and V1_Standby mode
2	V1_RESET_0	
1	WD_TIME_1	Watchdog Trigger Time 00: TSW1 (default) 01: TSW2 10: TSW3 11: TSW4 Writing to WD_TIME_x is blocked unless WD CONFIG EN = 1. The modified WD Trigger Time is valid immediately after the Write command (CSN transition low-high). The watchdog timer is reset when the trigger time is modified (restart at CSN transition low-high).
0	WD_TIME_0	

1. Timer restart behavior:
   Write to CR2 when Tx_ON_x and Tx_PERx remain unchanged:
   Tx_RESTART = 1: timers restart at end of SPI frame, starting with ON time
   Tx_RESTART = 0: write operation to CR2 has no effect on timers
   Write to CR2 when Tx_ON_x and Tx_PERx are modified
   Tx_RESTART = 1: timers restart at end of SPI frame, starting with ON time and according to new setting (ON time and period)
   Tx_RESTART = 0: behavior is not defined; if a predictable behavior is needed, it is recommended to set Tx_RESTART = 1

2. When V2 voltage regulator is configured in Tracking mode (V2_CONFIG=1 in Config Reg), the V1 Reset Threshold shall be configured to be the VRT1 (V1_RESET_1=1, V1_RESET_0=1 in CR2).

Table 98. Configuration of Timer x on-time

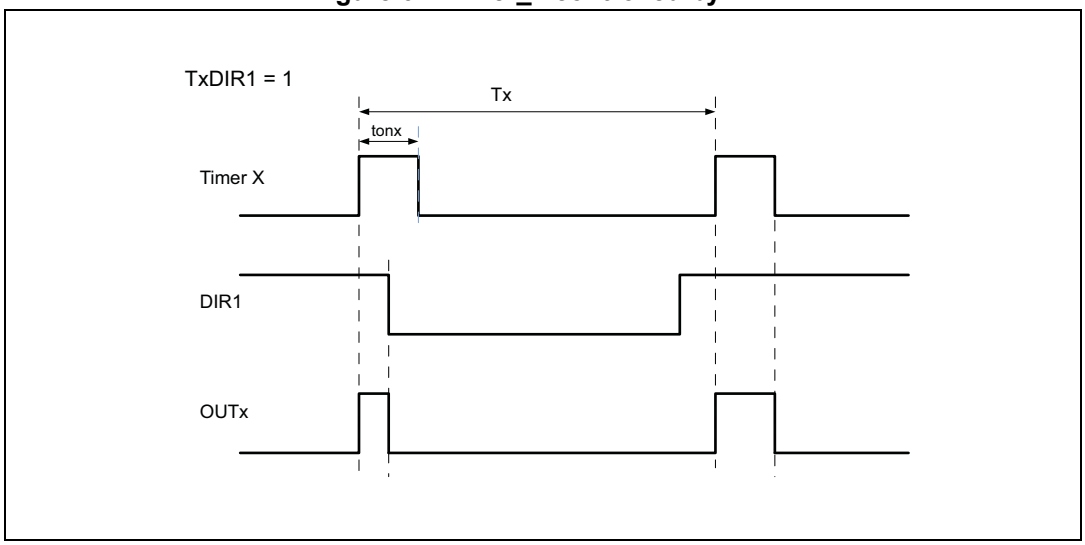
Tx_DIR	Tx_ON_2	Tx_ON_1	Tx_ON_0	Description
0	0	0	0	ton 1 (default)
0	0	0	1	ton 2
0	0	1	0	ton 3
0	0	1	1	ton 4
0	1	0	0	ton 5
0	1	0	1	Invalid setting; command will be ignored and *SPI_INV_CMD* will be set
0	1	1	0	
0	1	1	1	
1(1)	0	0	0	ton 1 controlled by DIR input signal (logical AND)
1(1)	0	0	1	ton 2 controlled by DIR input signal (logical AND)
1(1)	0	1	0	ton 3 controlled by DIR input signal (logical AND)
1(1)	0	1	1	ton 4 controlled by DIR input signal (logical AND)
1(1)	1	0	0	ton 5 controlled by DIR input signal (logical AND)

Table 98. Configuration of Timer x on-time (continued)

Tx_DIR	Tx_ON_2	Tx_ON_1	Tx_ON_0	Description
1(1)	1	0	1	Invalid setting; command will be ignored and *SPI_INV_CMD* will be set
1(1)	1	1	0	
1(1)	1	1	1	

1. Tx_DIR = 1 is only valid for OUT7-8-9-10-13-14-15 control; the DIR signal has no influence for WU monitoring if WU is monitored by timer.

Figure 64. Timer_x controlled by DIR



7.4.3 Control Register CR3 (0x03)

Figure 65. Control Register CR3

	23	22	21	20	19	18	17	16	15	14	13	12	11	1	9	8	7	6	5	4	3	2	1	0
Bit name	VSREG_LOCK_EN	VS_LOCK_EN	VSREG_OV_SD_EN	VSREG_UV_SD_EN	VS_OV_SD_EN	VS_UV_SD_EN	Reserved								VSREG_EWTH_9	VSREG_EWTH_8	VSREG_EWTH_7	VSREG_EWTH_6	VSREG_EWTH_5	VSREG_EWTH_4	VSREG_EWTH_3	VSREG_EWTH_2	VSREG_EWTH_1	VSREG_EWTH_0
Reset	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 99. CR3 signals description

Bit	Name	Description
23	VSREG_LOCK_EN	V_{SREG} lockout enable: Lockout of V_{SREG} related outputs after V_{SREG} overvoltage/ undervoltage shutdown 0: V_{SREG} related Outputs are turned on automatically and status bits (VSREG_UV, VSREG_OV) are cleared 1: V_{SREG} related Outputs remain turned off until status bits (VSREG_UV, VSREG_OV) are cleared (default) Lockout is always disabled in standby modes in order to ensure supply of external contacts and detect wake-up conditions
22	VS_LOCK_EN	V_S lockout enable: Lockout of V_S related outputs after V_S over/undervoltage shutdown 0: V_S related Outputs(1) are turned on automatically and status bits (VS_UV, VS_OV) are cleared 1: V_S related Outputs(1) remain turned off until status bits (VS_UV, VS_OV) are cleared (default) Lockout is always disabled in standby modes in order to ensure supply of external contacts and detect wake-up conditions
21	VSREG_OV_SD_EN	V_{SREG} overvoltage shutdown enable: shutdown of V_{SREG} related outputs in case of V_{SREG} overvoltage 0: no shutdown of V_{SREG} related outputs in case of V_{SREG} overvoltage 1: shutdown of V_{SREG} related outputs in case of V_{SREG} overvoltage (default)
20	VSREG_UV_SD_EN	V_{SREG} undervoltage shutdown enable: shutdown of V_{SREG} related outputs in case of V_{SREG} undervoltage 0: no shutdown of V_{SREG} related outputs in case of V_{SREG} undervoltage 1: shutdown of V_{SREG} related outputs in case of V_{SREG} undervoltage (default) In case of V1 undervoltage due to VSREG_UV, the device enters Fail-Safe mode and the outputs are turned off
19	VS_OV_SD_EN	V_S overvoltage shutdown enable: shutdown of V_S related outputs in case of V_S overvoltage 0: no shutdown of V_S related outputs in case of V_S overvoltage if charge pump output voltage is still sufficient (until CPLOW threshold is reached) 1: shutdown of V_S related outputs in case of V_S overvoltage (default)
18	VS_UV_SD_EN	V_S undervoltage shutdown enable: shutdown of V_S related outputs in case of V_S undervoltage 0: no shutdown of V_S related Outputs(1) in case of V_S undervoltage 1: shutdown of V_S related Outputs(1) in case of V_S undervoltage (default) In case of V1 undervoltage due to VS_UV, the device enters Fail-Safe mode and the outputs are turned off
17:10	Reserved	---

Table 99. CR3 signals description (continued)

Bit	Name	Description
9	VSREG_EW_TH_9	VSREG early warning threshold. At VSREG < VSREG_EW_TH, an interrupt is generated at NINT and status bit VSREG_EW in SR2 is set (in Active mode) 0000000000: 0 V (default) feature deactivated ... 1111111111: V_{AINVS}
8	VSREG_EW_TH_8	
7	VSREG_EW_TH_7	
6	VSREG_EW_TH_6	
5	VSREG_EW_TH_5	
4	VSREG_EW_TH_4	
3	VSREG_EW_TH_3	
2	VSREG_EW_TH_2	
1	VSREG_EW_TH_1	
0	VSREG_EW_TH_0	

1. "Vs related outputs" are OUT1 to OUT14 and H-bridge drivers (both A and B)

7.4.4 Control Register CR4 (0x04)

Figure 66. Control Register CR4

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved		OUT1_HS	OUT1_LS	Reserved		OUT2_HS	OUT2_LS	Reserved		OUT3_HS	OUT3_LS	Reserved										OUT6_HS	OUT6_LS
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 100. CR4 signals description

Bit	Name	Description
23:22	Reserved	Reserved
21	OUT1_HS	OUT1 High-Side Driver control 0: OUT1_HS is turned off (default) 1: OUT1_HS is turned on An internal cross-current protection prevents, that both the low- and high-side drivers of the half-bridge OUT1 are switched on simultaneously.
20	OUT1_LS	OUT1 Low-Side Driver control 0: OUT1_LS is turned off (default) 1: OUT1_LS is turned on An internal cross-current protection prevents, that both the low- and high-side drivers of the half-bridge OUT1 are switched on simultaneously.
19:18	Reserved	Reserved

Table 100. CR4 signals description (continued)

Bit	Name	Description
17	OUT2_HS	OUT2 High-Side Driver control 0: OUT2_HS is turned off (default) 1: OUT2_HS is turned on An internal cross-current protection prevents, that both the low- and high-side drivers of the half-bridge OUT2 are switched on simultaneously.
16	OUT2_LS	OUT2 Low-Side Driver control 0: OUT2_LS is turned off (default) 1: OUT2_LS is turned on An internal cross-current protection prevents, that both the low- and high-side drivers of the half-bridge OUT2 are switched on simultaneously.
15:14	Reserved	Reserved
13	OUT3_HS	OUT3 High-Side Driver control 0: OUT3_HS is turned off (default) 1: OUT3_HS is turned on An internal cross-current protection prevents, that both the low- and high-side drivers of the half-bridge OUT3 are switched on simultaneously.
12	OUT3_LS	OUT3 Low-Side Driver control 0: OUT3_LS is turned off (default) 1: OUT3_LS is turned on An internal cross-current protection prevents, that both the low- and high-side drivers of the half-bridge OUT3 are switched on simultaneously.
11:2	Reserved	--
1	OUT6_HS	OUT6 High-side Driver control 0: OUT6_HS is turned off (default) 1: OUT6_HS is turned on An internal cross-current protection prevents, that both the low-side and high-side drivers of the half-bridge OUT6 are switched on simultaneously.
0	OUT6_LS	OUT6 Low-side Driver control 0: OUT6_LS is turned off (default) 1: OUT6_LS is turned on An internal cross-current protection prevents, that both the low-side and high-side drivers of the half-bridge OUT6 are switched on simultaneously.

7.4.5 Control Register CR5 (0x05)

Figure 67. Control Register CR5

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT7_3	OUT7_2	OUT7_1	OUT7_0	OUT8_3	OUT8_2	OUT8_1	OUT8_0	Reserved				OUT10_3	OUT10_2	OUT10_1	OUT10_0	Reserved			GH	Reserved			
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 101. CR5 signals description

Bit	Name	Description
23	OUT7_3	OUT7 Configuration Bits: High-Side Driver OUT7 Configuration For OUT7 bits configuration see *Table 102: OUTx Configuration bits*
22	OUT7_2	
21	OUT7_1	
20	OUT7_0	
19	OUT8_3	OUT8 Configuration Bits: High-Side Driver OUT8 Configuration For OUT8 bits configuration see *Table 102: OUTx Configuration bits*
18	OUT8_2	
17	OUT8_1	
16	OUT8_0	
15:12	Reserved	—
11	OUT10_3	OUT10 Configuration Bits: High-Side Driver OUT10 Configuration For OUT10 bits configuration see *Table 102: OUTx Configuration bits*
10	OUT10_2	
9	OUT10_1	
8	OUT10_0	
7:5	Reserved	—
4	GH	Gate Heater Control: Control of gate driver for external heater MOSFET 0: GH_heater is turned off (default) 1: GH_heater is turned on
3:0	Reserved	—

Table 102. OUTx Configuration bits

OUTx_3	OUTx_2	OUTx_1	OUTx_0	Description
0	0	0	0	Off (default)
0	0	0	1	On
0	0	1	0	Timer1
0	0	1	1	Timer2
0	1	0	0	PWM1
0	1	0	1	PWM2
0	1	1	0	PWM3
0	1	1	1	PWM4
1	0	0	0	PWM5
1	0	0	1	PWM6
1	0	1	0	PWM7
1	0	1	1	Not Applicable

Table 102. OUTx Configuration bits (continued)

OUTx_3	OUTx_2	OUTx_1	OUTx_0	Description
1	1	0	0	Not Applicable
1	1	0	1	Not Applicable
1	1	1	0	DIR
1	1	1	1	Not Applicable

7.4.6 Control Register CR6 (0x06)

Figure 68. Control Register CR6

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT9_3	OUT9_2	OUT9_1	OUT9_0	OUT13_3	OUT13_2	OUT13_1	OUT13_0	OUT14_3	OUT14_2	OUT14_1	OUT14_0	OUT15_3	OUT15_2	OUT15_1	OUT15_0	Reserved							
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 103. CR6 signals description

Bit	Name	Description
23	OUT9_3	OUT9 Configuration Bits: High-Side Driver OUT9 Configuration For OUT9 bits configuration see *Table 102: OUTx Configuration bits*
22	OUT9_2	
21	OUT9_1	
20	OUT9_0	
19	OUT13_3	OUT13 Configuration Bits: High-Side Driver OUT13 Configuration For OUT13 bits configuration see *Table 102: OUTx Configuration bits*
18	OUT13_2	
17	OUT13_1	
16	OUT13_0	
15	OUT14_3	OUT14 Configuration Bits: High-Side Driver OUT14 Configuration For OUT14 bits configuration see *Table 102: OUTx Configuration bits*
14	OUT14_2	
13	OUT14_1	
12	OUT14_0	
11	OUT15_3	OUT15 Configuration Bits: High-side Driver OUT15 Configuration For OUT15 bits configuration see *Table 102: OUTx Configuration bits*
10	OUT15_2	
9	OUT15_1	
8	OUT15_0	
7:0	Reserved	—

7.4.7 Control Register CR7 (0x07)

Figure 69. Control Register CR7

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT1_OCR	OUT2_OCR	OUT3_OCR	OUT6_OCR	OUT7_OCR	OUT8_OCR	OUT15_OCR	Reserved				OUT1_SHORT_DIS	OUT2_SHORT_DIS	OUT3_SHORT_DIS	OUT6_SHORT_DIS	Reserved			CM_DIR_CONF_1	CM_DIR_CONF_0	CM_SEL_3	CM_SEL_2	CM_SEL_1	CM_SEL_0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 104. CR7 signals description

Bit	Name	Description
23	OUT1_OCR	Overcurrent recovery for OUTx 0: overcurrent recovery is turned off (default) 1: overcurrent recovery is turned on
22	OUT2_OCR	
21	OUT3_OCR	
20	OUT6_OCR	
19	OUT7_OCR	
18	OUT8_OCR	
17	OUT15_OCR	
16:13	Reserved	—
12	OUT1_SHORT_DIS	OUTx short circuit threshold disable 0: short circuit threshold is enabled (default) 1: short circuit threshold is disabled
11	OUT2_SHORT_DIS	
10	OUT3_SHORT_DIS	
9	OUT6_SHORT_DIS	
8:6	Reserved	—
5	CM_DIR_CONF_1	Current Monitor output or DIR input choice. CM_DIR_CONF_1 CM_DIR_CONF_0 00: CM all the time (default) 01: DIR when in Standby mode and CM when in Active mode 10: DIR all the time
4	CM_DIR_CONF_0	

Table 104. CR7 signals description (continued)

Bit	Name	Description
3	CM_SEL_3	Current Monitor Select Bits. A current image of the selected binary coded output is multiplexed to the CM output. If a corresponding output does not exist, the current monitor is deactivated. CM_SEL_3 CM_SEL_2 CM_SEL_1 CM_SEL_0 0000: OUT1 0001: OUT2 0010: OUT3 0011: NOT AVAILABLE 0100: NOT AVAILABLE 0101: OUT6 0110: OUT7 0111: OUT8 1000: OUT9 1001: OUT10 1010: NOT AVAILABLE 1011: NOT AVAILABLE 1100: OUT13 1101: OUT14 1110: OUT15 1111: NOT AVAILABLE
2	CM_SEL_2	
1	CM_SEL_1	
0	CM_SEL_0	

7.4.8 Control Register CR8 (0x08)

Figure 70. Control Register CR8

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT1_OCR_THX_EN	OUT2_OCR_THX_EN	OUT3_OCR_THX_EN	OUT6_OCR_THX_EN	OUT7_OCR_THX_EN	OUT8_OCR_THX_EN	OUT15_OCR_THX_EN	Reserved	OUT7_OCR_TON_1	OUT7_OCR_TON_0	OUT8_OCR_TON_1	OUT8_OCR_TON_0	OUT15_OCR_TON_1	OUT15_OCR_TON_0	OUTHB_OCR_TON_1	OUTHB_OCR_TON_0	OUT7_OCR_FREQ_1	OUT7_OCR_FREQ_0	OUT8_OCR_FREQ_1	OUT8_OCR_FREQ_0	OUT15_OCR_FREQ_1	OUT15_OCR_FREQ_0	OUTHB_OCR_FREQ_1	OUTHB_OCR_FREQ_0
Reset	1	1	1	1	1	1	1	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0
Access	R/W																							

Table 105. CR8 signals description

Bit	Name	Description
23	OUT1_OCR_THX_EN	Enable Overcurrent Recovery with Thermal Expiration for OUTx. 0: Overcurrent Recovery with Thermal Expiration is off 1: Overcurrent Recovery with Thermal Expiration is on (default). The output is turned off after Thermal Expiration.
22	OUT2_OCR_THX_EN	
21	OUT3_OCR_THX_EN	
20	OUT6_OCR_THX_EN	
19	OUT7_OCR_THX_EN	
18	OUT8_OCR_THX_EN	
17	OUT15_OCR_THX_EN	
16	Reserved	—
15	OUT7_OCR_TON_1	Auto-recovery programmable ON time for OUT7 OUT7_OCR_TON_1 OUT7_OCR_TON_0 00: 88 µs 01:80 µs (default) 10: 72 µs 11: 64 µs
14	OUT7_OCR_ TON _0	
13	OUT8_OCR_ TON _1	Auto-recovery programmable ON time for OUT8 OUT8_OCR_TON_1 OUT8_OCR_TON_0 00: 88 µs 01: 80 µs (default) 10: 72 µs 11: 64 µs
12	OUT8_OCR_ TON _0	
11	OUT15_OCR_TON _1	Auto-recovery programmable ON time for OUT15 OUT15_OCR_ TON _1 OUT15_OCR_ TON _0 00: 88 µs 01: 80 µs (default) 10: 72 µs 11: 64 µs
10	OUT15_OCR_TON _0	
9	OUTHB_OCR_ TON _1	Auto-recovery programmable ON time for HB (OUT1, OUT2, OUT3, OUT6) OUTHB_OCR_ TON _1 OUTHB_OCR_TON_0 00: 88 µs 01: 80 µs (default) 10: 72 µs 11: 64 µs
8	OUTHB_OCR_TON_0	

Table 105. CR8 signals description (continued)

Bit	Name	Description
7	OUT7_OCR_FREQ_1	Auto-recovery programmable frequency for OUT7 OUT7_OCR_FREQ_1 OUT7_OCR_FREQ_0 00: 1.7 kHz (default) 01: 2.2 kHz 10: 3.0 kHz 11: 4.4 kHz
6	OUT7_OCR_FREQ_0	
5	OUT8_OCR_FREQ_1	Auto-recovery programmable frequency for OUT8 OUT8_OCR_FREQ_1 OUT8_OCR_FREQ_0 00: 1.7 kHz (default) 01: 2.2 kHz 10: 3.0 kHz 11: 4.4 kHz
4	OUT8_OCR_FREQ_0	
3	OUT15_OCR_FREQ_1	Auto-recovery programmable frequency for OUT15 OUT15_OCR_FREQ_1 OUT15_OCR_FREQ_0 00: 1.7 kHz (default) 01: 2.2 kHz 10: 3.0 kHz 11: 4.4 kHz
2	OUT15_OCR_FREQ_0	
1	OUTHB_OCR_ FREQ_1(1)	Auto-recovery programmable frequency for OUTHB (OUT1, OUT2, OUT3, OUT6) OUTHB_OCR_FREQ_1 OUTHB_OCR_FREQ_0 00: 1.7 kHz (default) 01: 2.2 kHz 10: 3.0 kHz 11: 4.4 kHz
0	OUTHB_OCR_ FREQ_0(1)	

1. For OUT1 and OUT6, in case the Short Circuit detection is disabled and the OCR is enabled, the OCR configurations with frequency 3.0 kHz and 4.4kHz (whatever is the configured Ton value) are NOT allowed.

7.4.9 Control Register CR9 (0x09)

Figure 71. Control Register CR9

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT8_RDSON	OUT7_RDSON	OUT1_6_RDSON	OUT9_CCM_EN	OUT8_CCM_EN	OUT7_CCM_EN	Reserved			OUT15_OL	OUT14_OL	OUT13_OL	Reserved		OUT10_OL	OUT9_OL	Reserved	OUT15_OC	OUT14_OC	OUT13_OC	Reserved		OUT10_OC	OUT9_OC
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 106. CR9 signals description

Bit	Name	Description
23	OUT8_RDSON	Select Rdson for OUT8 0: ron_low (default) 1: ron_high
22	OUT7_RDSON	Select Rdson for OUT7 0: ron_low (default) 1: ron_high
21	OUT1_6_RDSON	Select Rdson for both OUT6 and OUT1 0: ron_low (default) 1: ron_high
20	OUT9_CCM_EN	Enable Constant Current Mode for OUT9 0: Disable (default) 1: Enable
19	OUT8_CCM_EN	Enable Constant Current Mode for OUT8 0: Disable (default) 1: Enable
18	OUT7_CCM_EN	Enable Constant Current Mode for OUT7 0: Disable (default) 1: Enable
17:15	Reserved	—

Table 106. CR9 signals description (continued)

Bit	Name	Description
14	OUT15_OL	Open-load Threshold for OUTx 0: I_{OLD1}; high-current mode (default) 1: I_{OLD1}; low-current mode
13	OUT14_OL	
12	OUT13_OL	
11:10	Reserved	
9	OUT10_OL	
8	OUT9_OL	
7	Reserved	—
6	OUT15_OC	Overcurrent Threshold for OUTx 0: I_{OC}; high-current mode (default) 1: I_{OC}; low-current mode
5	OUT14_OC	
4	OUT13_OC	
3:2	Reserved	
1	OUT10_OC	
0	OUT9_OC	

7.4.10 Control Register CR10 (0x0A)

Figure 72. Control Register CR10

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	DIAG_2_A	DIAG_1_A	DIAG_0_A	DIRHA	SD2B	SDS2B	SD1B	SDS1B	SD2A	SDS2A	SD1A	SDS1A	COPT_3_A	COPT_2_A	COPT_1_A	COPT_0_A	H_OLTH_HIGH_	OL_H1L2_A	OL_H2L1_A	SLEW_4_A	SLEW_3_A	SLEW_2_A	SLEW_1_A	SLEW_0_A
Reset	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Access	R/W																							

Table 107. CR10 signals description

Bit	Name	Description
23	DIAG_2_A	Drain-source monitoring threshold for external H-bridge A DIAG_2_A DIAG_1_A DIAG_0_A

Table 107. CR10 signals description (continued)

Bit	Name	Description
22	DIAG_1_A	000: V_{SCd1_HB} 001: V_{SCd2_HB} 010: V_{SCd3_HB} 011: V_{SCd4_HB} 100: V_{SCd5_HB} 101: V_{SCd6_HB} 110: V_{SCd7_HB} 111: V_{SCd7_HB} (default)
21	DIAG_0_A	
20	DIRHA	Direction of the H-Bridge A 0: HS2a and LS1a are ON; HS1a and LS2a are OFF (default) 1: HS1a and LS2a are ON; HS2a and LS1a are OFF
19	SD2B	Slow decay for leg 2 of the H-bridge B
18	SDS2B	Slow decay Single for leg 2 of the H-bridge B
17	SD1B	Slow decay for leg 1 of the H-bridge B
16	SDS1B	Slow decay Single for leg 1 of the H-bridge B
15	SD2A	Slow decay for leg 2 of the H-bridge A
14	SDS2A	Slow decay Single for leg 2 of the H-bridge A
13	SD1A	Slow decay for leg 1 of the H-bridge A
12	SDS1A	Slow decay Single for leg 1 of the H-bridge A
11	COPT_3_A	Cross current protection time (H-Bridge A) COPT_3_A COPT_2_A COPT_1_A COPT_0_A 0000: $tccp_{0000}$ 0001: $tccp_{0001}$ 0010: $tccp_{0010}$ 0011: $tccp_{0011}$ 0100: $tccp_{0100}$ 0101: $tccp_{0101}$ 0110: $tccp_{0110}$ 0111: $tccp_{0111}$ 1000: $tccp_{1000}$ 1001: $tccp_{1001}$ 1010: $tccp_{1010}$ 1011: $tccp_{1011}$ 1100: $tccp_{1100}$ 1101: $tccp_{1101}$ 1110: $tccp_{1110}$ 1111: $tccp_{1111}$ (default)
10	COPT_2_A	
9	COPT_1_A	
8	COPT_0_A	
7	H_OLTH_HIGH_A	H-bridge A OL high threshold (5/6 * V_S) select
6	OL_H1L2_A	Test open-load condition between H1 and L2 of the H-Bridge A
5	OL_H2L1_A	Test open-load condition between H2 and L1 for H-bridge A

Table 107. CR10 signals description (continued)

Bit	Name	Description
4	SLEW_4_A	Binary coded slew rate of H-bridge A SLEW_4_A SLEW_3_A SLEW_2_A SLEW_1_A SLEW_0_A (bit0 = LSB; bit4 = MSB) 00000: Control disabled (default) 11111: I_{GHxmax}
3	SLEW_3_A	
2	SLEW_2_A	
1	SLEW_1_A	
0	SLEW_0_A	

7.4.11 Control Register CR11 (0x0B)

Figure 73. Control Register CR11

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved						GH_OL_EN	GH_TH_2	GH_TH_1	GH_TH_0	ECV_LS	ECV_OCR	Reserved			ECON	Reserved		EC_5	EC_4	EC_3	EC_2	EC_1	EC_0
Reset	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 108. CR11 signals description

Bit	Name	Description
23:18	Reserved	—
17	GH_OL_EN	Control open-load diagnosis for Gate Heater output 0: open-load diagnosis off (default) 1: open-load diagnosis on
16	GH_TH_2	Drain source monitoring threshold voltage for external heater MOSFET GH_TH_2 GH_TH_1 GH_TH_0 000: V_{SCd1_HE} 001: V_{SCd2_HE} 010: V_{SCd3_HE} 011: V_{SCd4_HE} 100: V_{SCd5_HE} 101: V_{SCd6_HE} 110: V_{SCd7_HE} 111: V_{SCd8_HE} (default)
15	GH_TH_1	
14	GH_TH_0	
13	ECV_LS	Control of ECV low-side switch 0: ECV low-side switch off (default) 1: ECV low-side switch on

Table 108. CR11 signals description (continued)

Bit	Name	Description
12	ECV_OCR	Overcurrent recovery for output ECV 0: overcurrent recovery is turned off (default) 1: overcurrent recovery is turned on
11:9	Reserved	—
8	ECON	Electro-chrome Control The electro-chrome control enables the driver at pin ECDR and switches OUT10 directly on ignoring the control bits OUT10_x in CR5 0: Electro-chrome control off (default) 1: Electro-chrome control on
7:6	Reserved	—
5	EC_5	EC Reference Voltage Bits The reference voltage for the electro-chrome voltage controller at pin ECV is binary coded. (bit0 = LSB; bit5 = MSB) 00 0000: V_{ECV} = 0 V xx xxxx: V_{ECV} = $V_{CTRLmax}$/63 x register value 11 1111: V_{ECV} = $V_{CTRLmax}$ For ECV_HV (Configuration Register) = 0, the maximum EC control voltage is clamped at lower value (see *Section 3.4.20: Electro-chrome mirror driver*) EC_x bits are set to 0 after wake-up from VBAT_Standby mode
4	EC_4	
3	EC_3	
2	EC_2	
1	EC_1	
0	EC_0	

7.4.12 Control Register CR12 (0x0C)

Figure 74. Control Register CR12

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	PMW1_FREQ_1	PMW1_FREQ_0	PMW2_FREQ_1	PMW2_FREQ_0	PMW3_FREQ_1	PMW3_FREQ_0	PMW4_FREQ_1	PMW4_FREQ_0	PMW5_FREQ_1	PMW5_FREQ_0	PMW6_FREQ_1	PMW6_FREQ_0	PMW7_FREQ_1	PMW7_FREQ_0	Reserved									
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 109. CR12 signals description

Bit	Name	Description
23	PMW1_FREQ_1	Frequency of PWM channel PWM1 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
22	PMW1_FREQ_0	
21	PMW2_FREQ_1	Frequency of PWM channel PWM2 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
20	PMW2_FREQ_0	
19	PMW3_FREQ_1	Frequency of PWM channel PWM3 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
18	PMW3_FREQ_0	
17	PMW4_FREQ_1	Frequency of PWM channel PWM4 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
16	PMW4_FREQ_0	
15	PMW5_FREQ_1	Frequency of PWM channel PWM5 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
14	PMW5_FREQ_0	
13	PMW6_FREQ_1	Frequency of PWM channel PWM6 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
12	PMW6_FREQ_0	
11	PMW7_FREQ_1	Frequency of PWM channel PWM7 00: f_{PWMx}(00) (default) 01: f_{PWMx}(01) 10: f_{PWMx}(10) 11: f_{PWMx}(11)
10	PMW7_FREQ_0	
9:0	Reserved	—

7.4.13 Control Register CR13 (0x0D) to CR16 (0x10)

Figure 75. Control Register CR13 to CR16

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved		PWMx_DC_9	PWMx_DC_8	PWMx_DC_7	PWMx_DC_6	PWMx_DC_5	PWMx_DC_4	PWMx_DC_3	PWMx_DC_2	PWMx_DC_1	PWMx_DC_0	Reserved		PWMy_DC_9	PWMy_DC_8	PWMy_DC_7	PWMy_DC_6	PWMy_DC_5	PWMy_DC_4	PWMy_DC_3	PWMy_DC_2	PWMy_DC_1	PWMy_DC_0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

where: x = 1 + (z * 2), z = 0 to 3
y = 2 + (z * 2), z = 0 to 2

Table 110. CR13 to CR16 signals description

Bit	Name	Description
23:22	Reserved	—
21	PWMx_DC_9	Binary coded on-duty cycle of PWM channel PWMx (bit12 = LSB; bit21 = MSB) 00 0000 0000: duty cycle 0% (default) xx xxxx xxxx: duty cycle 100%/1024 x register value 11 1111 1111. duty cycle 99,9% (1)
20	PWMx_DC_8	
19	PWMx_DC_7	
18	PWMx_DC_6	
17	PWMx_DC_5	
16	PWMx_DC_4	
15	PWMx_DC_3	
14	PWMx_DC_2	
13	PWMx_DC_1	
12	PWMx_DC_0	
11:10	Reserved	—
9	PWMy_DC_9	Binary coded on-duty cycle of PWM channel PWMy (bit0 = LSB; bit9 = MSB) 00 0000 0000: duty cycle 0% (default) xx xxxx xxxx: duty cycle 100%/ 1024 x register value 11 1111 1111. Duty cycle 99,9%(1) Binary coded on-duty cycle of PWM channel PWMy
8	PWMy_DC_8	
7	PWMy_DC_7	
6	PWMy_DC_6	
5	PWMy_DC_5	
4	PWMy_DC_4	
3	PWMy_DC_3	
2	PWMy_DC_2	
1	PWMy_DC_1	
0	PWMy_DC_0	

1. To have Duty Cycle equal to 100% for the Output X (where X = 7, 8, 9, 10, 13, 14, 15), the related Output Configuration shall be set in ON mode (OUTX_3-2-1-0 = 0001; see *Table 102: OUTx Configuration bits*).

7.4.14 Control Register CR17 (0x11) to CR20 (0x14)

Figure 76. Control Registers CR17-CR20

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved	OUTx_AUTOCOMP_EN	OUTx_VLED_9	OUTx_VLED_8	OUTx_VLED_7	OUTx_VLED_6	OUTx_VLED_5	OUTx_VLED_4	OUTx_VLED_3	OUTx_VLED_2	OUTx_VLED_1	OUTx_VLED_0	Reserved	OUTy_AUTOCOMP_EN	OUTy_VLED_9	OUTy_VLED_8	OUTy_VLED_7	OUTy_VLED_6	OUTy_VLED_5	OUTy_VLED_4	OUTy_VLED_3	OUTy_VLED_2	OUTy_VLED_1	OUTy_VLED_0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

where: x = 7 + (z * 2), z = 0, 1, 3, 4

y = 8 + (z * 2), z = 0, 1, 3

Table 111. CR17 to CR20 signals description

Bit	Name	Description
23	Reserved	—
22	OUTx_AUTOCOMP_EN	Setting this bit to ‘1’ enables the automatic V_S compensation for OUTx
21	OUTx_VLED_9	Binary coded nominal LED voltage of OUTx (bit12 = LSB; bit21 = MSB) 00 0000 0000: V_{LED} = 0 V (default) xx xxxx xxxx: V_{LED} = V_{AINVS} /1024 x register value 01 1101 0000: V_{LED} = V_{AINVS} V_{LED} is clamped at 10 V (0x1D0h)
20	OUTx_VLED_8	
19	OUTx_VLED_7	
18	OUTx_VLED_6	
17	OUTx_VLED_5	
16	OUTx_VLED_4	
15	OUTx_VLED_3	
14	OUTx_VLED_2	
13	OUTx_VLED_1	
12	OUTx_VLED_0	
11	Reserved	—
10	OUTy_AUTOCOMP_EN	Setting this bit to ‘1’ enables the automatic V_S compensation for OUTy

Table 111. CR17 to CR20 signals description (continued)

Bit	Name	Description
9	OUTy_VLED_9	Binary coded nominal LED voltage of OUTy (bit0 = LSB; bit9 = MSB) 00 0000 0000: V_{LED} = 0 V (default) xx xxxx xxxx: V_{LED} = V_{AINVS} /1024 x register value 01 1101 0000: V_{LED} = V_{AINVS} V_{LED} is clamped at 10 V (0x1D0h)
8	OUTy_VLED_8	
7	OUTy_VLED_7	
6	OUTy_VLED_6	
5	OUTy_VLED_5	
4	OUTy_VLED_4	
3	OUTy_VLED_3	
2	OUTy_VLED_2	
1	OUTy_VLED_1	
0	OUTy_VLED_0	

7.4.15 Control Register CR21 (0x15)

Figure 77. Control Register CR21

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	DIAG_2_B	DIAG_1_B	DIAG_0_B	DIRHB	Reserved								COPT_3_B	COPT_2_B	COPT_1_B	COPT_0_B	H_OLTH_HIGH_B	OL_H1L2_B	OL_H2L1_B	SLEW_4_B	SLEW_3_B	SLEW_2_B	SLEW_1_B	SLEW_0_B
Reset	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Access	R/W																							

Table 112. CR21 signals description

Bit	Name	Description
23	DIAG_2_B	Drain-source monitoring threshold for external H-bridge B DIAG_2_B DIAG_1_B DIAG_0_B
22	DIAG_1_B	000: V_{SCd1_HB} 001: V_{SCd2_HB} 010: V_{SCd3_HB} 011: V_{SCd4_HB} 100: V_{SCd5_HB} 101: V_{SCd6_HB} 110: V_{SCd7_HB} 111: V_{SCd7_HB} (default)
21	DIAG_0_B	
20	DIRHB	Direction of the H-bridge B 0: HS2b and LS1b are ON; HS1b and LS2b are OFF (default) 1: HS1b and LS2b are ON; HS2b and LS1b are OFF
19:12	Reserved	—
11	COPT_3_B	Cross current protection time (H-bridge B) COPT_3_B COPT_2_B COPT_1_B COPT_0_B 0000: $tccp_{0000}$ 0001: $tccp_{0001}$ 0010: $tccp_{0010}$ 0011: $tccp_{0011}$ 0100: $tccp_{0100}$ 0101: $tccp_{0101}$ 0110: $tccp_{0110}$ 0111: $tccp_{0111}$ 1000: $tccp_{1000}$ 1001: $tccp_{1001}$ 1010: $tccp_{1010}$ 1011: $tccp_{1011}$ 1100: $tccp_{1100}$ 1101: $tccp_{1101}$ 1110: $tccp_{1110}$ 1111: $tccp_{1111}$ (default)
10	COPT_2_B	
9	COPT_1_B	
8	COPT_0_B	
7	H_OLTH_HIGH_B	H-bridge B OL high threshold (5/6 * V_S) select
6	OL_H1L2_B	Test open-load condition between H1 and L2 of the H-Bridge B
5	OL_H2L1_B	Test open-load condition between H2 and L1 for H-bridge B

Table 112. CR21 signals description (continued)

Bit	Name	Description
4	SLEW_4_B	Binary coded slew rate of H-bridge B SLEW_4_B SLEW_3_B SLEW_2_B SLEW_1_B SLEW_0_B (bit0 = LSB; bit4 = MSB) 00000: Control disabled (default) 11111: I_{GHxmax}
3	SLEW_3_B	
2	SLEW_2_B	
1	SLEW_1_B	
0	SLEW_0_B	

7.4.16 Control Register CR22 (0x16)

Figure 78. Control Register CR22

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved																			GENERATOR_MODE_EN	DEBUG_EXIT	CP_OFF	ICMP	WD_EN
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Access	R/W																							

Table 113. CR22 signals description

Bit	Name	Description
23:5	Reserved	—
4	GENERATOR_MODE_EN	Generator Mode control enable: 0: Generator Mode is disabled 1: Generator Mode is enabled (default)
3	DEBUG_EXIT	SW-Debug mode exit 0: stay in SW-Debug mode (default) 1: exit from SW Debug mode When exiting from SW-Debug mode, the watchdog starts with a Long Open Window. This bit has only effect in SW-Debug mode (no effect in Normal mode)
2	CP_OFF	Charge pump control 0: Enabled; charge pump on in active mode (default) 1: Disabled; charge pump off in active mode setting CP_OFF = 1 is only possible when CP_OFF_EN = 1

Table 113. CR22 signals description (continued)

Bit	Name	Description
1	ICMP	V1 load current supervision 0: Enabled; Watchdog is disabled in V1 Standby when $I_{V1} < I_{CMP}$ (default) 1: Disabled; watchdog is disabled upon transition into V1_Standby mode setting ICMP = 1 is only possible when ICMP_CONFIG_EN = 1
0	WD_EN	Watchdog Enable 0: Watchdog disabled 1: Watchdog enabled (default) Writing to this bit is only possible during CAN Flash mode ($V_{TxDL} > V_{flash}$)

7.4.17 Configuration Register (0x3F)

Figure 79. Configuration Register

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	WU_CONFIG	LIN_WU_CONFIG	LIN_HS_EN	TSD_CONFIG	ECV_HV	V2_CONFIG	ICMP_CONFIG_EN	WD_CONFIG_EN	MASK_OL_HS1	MASK_OL_LS1	MASK_TW	MASK_EC_OL	MASK_OL	MASK_SPIE	MASK_PLE	MASK_GW	CP_OFF_EN	CP_LOW_CONFIG	CP_DITH_DIS	FS_FORCED	Reserved	DMA	DMB	TRIG
Reset	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Access	R/W																							

Table 114. Configuration Register signals description

Bit	Name	Description
23	WU_CONFIG	Configuration of input pin WU Input configured as wake-up input 0: WU configured as wake-up input 1: WU configured for input voltage measurement (default)
22	LIN_WU_CONFIG	Configuration of LIN wake-up behavior 0: wake up at recessive - dominant - recessive with $t_{dom} > t_{dom\_LIN}$ (default) (according to LIN 2.2a and Hardware Requirements for Transceivers version 1.3) 1: wake up at recessive - dominant transition
21	LIN_HS_EN	Configuration of LIN transceiver bit rate 0: LIN transceiver in normal communication mode (20kbit/s) (default) 1: LIN transceiver in high speed mode for fast Flashing (115kbit/s)
20	TSD_CONFIG	Configuration of thermal shutdown behavior 0: in case of TSD1 all power stages are switched off (default) 1: selective shut down of power stage cluster

Table 114. Configuration Register signals description (continued)

Bit	Name	Description
19	ECV_HV	Configuration of maximum voltage of electrochrome controller (see electrical parameter $V_{CTRLmax}$) 0: maximum electrochrome controller voltage clamped to 1.2V (typ); (default) 1: maximum electrochrome controller voltage set to 1.5V (typ)
18	V2_CONFIG	Configuration of V2 0: V2 is Voltage Regulator (default) 1: V2 is Voltage Tracker of V1
17	ICMP_CONFIG_EN	ICMP configuration Enable 0: writing ICMP = 1 is blocked (writing ICMP=0 is possible); (default) 1: writing ICMP = 1 is possible with next SPI command bit is automatically reset to 0 after next SPI command
16	WD_CONFIG_EN	Watchdog configuration Enable 0: writing to WD Configuration (CR2 [0:1] is blocked (default) 1: writing to WD Configuration Bits is possible with next SPI command bit is automatically reset to 0 after next SPI command
15	MASK_OL_HS1	Mask Open-load HS1 0: Open-load condition at HS1 is not masked (default) 1: Open-load condition at HS1 is masked i.e. it is reported as a Functional Error (GSB bit 3) but not as a Global Error (GSB bit 7)
14	MASK_OL_LS1	Mask Open-load LS1 0: Open-load condition at LS1 is not masked (default) 1: Open-load condition at LS1 is masked i.e. it is reported as a Functional Error (GSB bit 3) but not as a Global Error (GSB bit 7)
13	MASK_TW	Mask Thermal Warning 0: Thermal warning is not masked (default) 1: Thermal warning is masked i.e. it is reported as a Global Warning (GSB bit 1) but not as a Global Error (GSB bit 7)
12	MASK_EC_OL	Mask Electro-chrome Open-load 0: Open-load condition at ECV and OUT10 is not masked (default) 1: Open-load condition at ECV and OUT10 is masked i.e. it is reported as a Functional Error (GSB bit 3) but not as a Global Error (GSB bit 7)
11	MASK_OL	Mask open-load 0: Open-load condition at all outputs are not masked (default) 1: Open-load condition at all outputs are masked i.e. it is reported as a Functional Error (GSB bit 3) but not as a Global Error (GSB bit 7)
10	MASK_SPIE	Mask SPI error 0: SPI errors are not masked (default) 1: SPI errors are masked i.e. reported as an SPI Error (GSB bit 5) but not as a Global Error (GSB bit 7)

Table 114. Configuration Register signals description (continued)

Bit	Name	Description
9	MASK_PLE	Mask physical layer error 0: Physical Layer Errors are not masked (default) 1: Physical Layer Errors are masked i.e. reported as a Physical Layer Error (GSB bit 4) but not as a Global Error (GSB bit 7)
8	MASK_GW	Mask global warning 0: Global Warning conditions are not masked (default) 1: Global Warning conditions are masked i.e. reported as a Global Warning (GSB bit 1) but not as a Global Error (GSB bit 7)
7	CP_OFF_EN	Charge pump control enable 0: writing CP_OFF = 1 is blocked (writing CP OFF = 0 is possible); (default) 1: writing CP_OFF = 1 is possible with next SPI command Bit is automatically reset to 0 after next SPI command
6	CP_LOW_CONFIG	Charge pump low configuration 0: CP_low (SR 2, bit 9) is latched and outputs are off until R&C; (default) 1: CP_low (SR 2, bit 9) is a 'live' bit; outputs are re-activated automatically upon recovery of the charge pump output voltage
5	CP_DITH_DIS	Charge pump clock dithering 0: CP clock dithering is enabled; (default) 1: CP clock dithering is disabled
4	FS_FORCED	Force LSx_FSO ON LSx_FSO low-side outputs are forced ON (to allow diagnosis of the fail-safe path) 0: LSx_FSO outputs are controlled by the Fail-safe logic (default) 1: LSx_FSO outputs are forced ON and the device enters Fail-Safe mode; no NReset is generated
3	Reserved	—
2:1	DMA	H-bridge A configuration 0: single motor mode (default) 1: dual motor mode
	DMB	H-bridge B configuration 0: single motor mode (default) 1: dual motor mode
0	TRIG	Watchdog Trigger bit

7.5 Status registers

7.5.1 Status Register SR1 (0x31)

Figure 80. Status Register SR1 (0x31)

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	VS_OV_WAKEUP	WU_STATE	SGND_LOSS	WU_WAKE	WAKE_CAN	WAKE_LIN	WAKE_TIMER	DEBUG_ACTIVE	V1UV	V1_RESTART_2	V1_RESTART_1	V1_RESTART_0	WDFAIL_CNT_3	WDFAIL_CNT_2	WDFAIL_CNT_1	WDFAIL_CNT_0	DEVICE_STATE_1	DEVICE_STATE_0	TSD2	TSD1	FORCED_SLEEP_TSD2/V1SC	FORCED_SLEEP_WD	WDFAIL	VPOR
Access	R/C	R	R/C							R							R/C							

Table 115. SR1 signals description

Bit	Name	Description
23	VS_OV_WAKEUP	Wake-up by VS OV: shows wake up source 1: wake-up Bits are latched until a “Read and clear” command
22	WU_STATE	State of WU input 0: input level is low 1: input level is high The bit shows the momentary status of WU and cannot be cleared (“Live bit”) Note: The status is only valid if WU is configured as wake-up input in Configuration Register (0x3F). Otherwise this bit is read at its previous logic state
21	SGND_LOSS	SGND Loss: shows the Signal GND loss 1: SGND Loss Bit is latched until a “Read and clear” command
20	WU_WAKE	Wake-up by WU: shows wake up source 1: wake-up Bits are latched until a “Read and clear” command
19	WAKE_CAN	Wake-up by CAN: shows wake up source 1: wake-up Bits are latched until a “Read and clear” command
18	WAKE_LIN	Wake-up by LIN: shows wake up source 1: wake-up Bits are latched until a “Read and clear” command

Table 115. SR1 signals description (continued)

Bit	Name	Description
17	WAKE_TIMER	Wake-up by Timer: shows wake up source 1: wake-up Bits are latched until a “Read and clear” command
16	DEBUG_ACTIVE	Debug Mode Active: indicates Device is in Debug mode 1: Debug mode The bit shows the momentary status and cannot be cleared (“Live bit”)
15	V1UV	Indicates undervoltage condition at voltage regulator V1 (V1 < V_{RTx}) 1: undervoltage Bit is latched until a “Read and clear” command
14	V1_RESTART_2	Indicates the number of TSD2 events which caused a restart of voltage regulator V1 Bits cannot be cleared; counter will be cleared automatically if no additional TSD2 event occurs within 1 minute.
13	V1_RESTART_1	
12	V1_RESTART_0	
11	WDFAIL_CNT_3	Indicates number of subsequent watchdog failures. Bits cannot be cleared; will be cleared with a valid watchdog trigger
10	WDFAIL_CNT_2	
9	WDFAIL_CNT_1	
8	WDFAIL CNT_0	
7	DEVICE_STATE_1	State from which the device woke up 00: Active mode, after Read&Clear command or after Flash mode state 01: Active mode after wake-up from V1_Standby mode (before Read&Clear command) 10: in Active mode after Power-on or after wake-up from VBAT_Standby mode (before Read&Clear command) 11: Flash mode (LIN Flash or CAN Flash mode) Bit is latched until a “Read and clear” command After a “read and clear access”, the device state will be updated
6	DEVICE_STATE_0	
5	TSD2	Thermal Shutdown 2 was reached Bit is latched until a "Read and clear" command
4	TSD1	Thermal Shutdown 1 was reached (Logical Or combination of all TSD1_CLx; see status register SR6). This bit cannot be cleared directly. It is reset if the corresponding TSD1_CLx bits in SR6 are cleared.
3	FORCED_SLEEP_ TSD2/V1SC	Device entered Forced VBAT_Standby mode due to: Thermal shutdown or Short circuit on V1 during startup Bit is latched until a "Read and clear" command
2	FORCED_SLEEP_WD	Device entered Forced VBAT_Standby mode due to multiple watchdog failures Bit is latched until a "Read and clear" command

Table 115. SR1 signals description (continued)

Bit	Name	Description
1	WDFAIL	Watchdog failure Bit is latched until a "Read and clear" command
0	VPOR	Vs Power-on Reset threshold (VPOR) reached Bit is latched until a "Read and clear" command

7.5.2 Status Register SR2 (0x32)

Figure 81. Status Register SR2 (0x32)

	23	22	21	20	19	18	17	16	1	14	13	1	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	LIN_PERM_DOM	LIN_TXD_DOM	LIN_PERM_REC	CAN_RXD_REC	CAN_PERM_REC	CAN_PERM_DOM	CAN_TXD_DOM	CAN_SUP_LOW	DSMON_HS2_A	DSMON_HS1_A	DSMON_LS2_A	DSMON_LS1_A	SPI_INV_CMD	SPI_SCK_CNT	CP_LOW	TW	V2SC	V2FAIL	V1FAIL	VSREG_EW	VSREG_OV	VSREG_UV	VS_OV	VS_UV
Access	R/C													R	R/C									

Table 116. SR2 signals description

Bit	Name	Description
23	LIN_PERM_DOM	LIN bus signal is dominant for t > $t_{dom(bus)}$ Bit is latched until a “Read and clear” command
22	LIN_TXD_DOM	TxD_L pin is dominant for t > $t_{dom(TXDL)}$ The LIN transmitter is disabled until the bit is cleared Bit is latched until a “Read and clear” command
21	LIN_PERM_REC	LIN bus signal does not follow TxD_L within t_{LIN} The LIN transmitter is disabled until the bit is cleared Bit is latched until a “Read and clear” command
20	CAN_RXD_REC	RxD_C has not followed TxD_C for 4 times The CAN transmitter is disabled until the bit is cleared Bit is latched until a “Read and clear” command
19	CAN_PERM_REC	CAN bus signal did not follow TxD_C for 4 times The CAN transmitter is disabled until the bit is cleared Bit is latched until a “Read and clear” command
18	CAN_PERM_DOM	CAN bus signal is dominant for t > t_{CAN} Bit is latched until a “Read and clear” command
17	CAN_TXD_DOM	TxD_C pin is dominant for t > $t_{dom(TXDC)}$ The CAN transmitter is disabled until the bit is cleared Bit is latched until a “Read and clear” command

Table 116. SR2 signals description (continued)

Bit	Name	Description
16	CAN_SUP_LOW	Voltage at CAN supply pin reached the CAN supply low warning threshold $V_{CANSUP} < V_{CANSUPlow}$ Bit is latched until a “Read and clear” command
15	DSMON_HS2_A	Drain-Source Monitoring for H-bridge A ‘1’ indicates a short-circuit or open-load condition was detected Bit is latched until a “Read and clear” command
14	DSMON_HS1_A	
13	DSMON_LS2_A	
12	DSMON_LS1_A	
11	SPI_INV_CMD	Invalid SPI command ‘1’ indicates one of the following conditions was detected: – access to undefined address – Write operation to Status Register – DI stuck at '0' or '1' – CSN timeout – Parity failure – invalid or undefined setting – SPI access during VS_OV conditions (when Generator_Mode_EN = 1) The SPI frame is ignored Bit is latched until a “Read and clear” command
10	SPI_SCK_CNT	SPI clock counter ‘1’ indicates an SPI frame with wrong number of CLK cycles was detected Bit is latched until a valid SPI frame
9	CP_LOW	Charge pump voltage low ‘1’ indicates that the charge pump voltage is too low Bit is latched until a “Read and clear” command
8	TW	Thermal warning ‘1’ indicates the temperature has reached the thermal warning threshold (logical OR combination of bits TW_CLx in SR6) Bit is latched until a “Read and clear” command
7	V2SC	V2 short circuit detection ‘1’ indicates a short circuit to GND condition of V2 at turn-on of the regulator (V2 < V2_fail for $t > t_{v2\_short}$) Bit is latched until a “Read and clear” command
6	V2FAIL	V2 failure detection ‘1’ indicates a V2 fail event occurred since last readout (V2 < V2_fail for $t > t_{v2\_fail}$) Bit is latched until a “Read and clear” command
5	V1FAIL	V1 failure detection ‘1’ indicates a V1 fail event occurred since last readout (V1 < V1_fail for $t > t_{v1\_fail}$) Bit is latched until a “Read and clear” command

Table 116. SR2 signals description (continued)

Bit	Name	Description
4	VSREG_EW	V_{SREG} early warning '1' indicates the voltage at V_{SREG} has reached the early warning threshold (configured in CR3) In Active mode, an interrupt pulse is generated at NINT Bit is latched until a "Read and clear" command. Bit needs a "Read and clear" command after wake-up from standby modes
3	VSREG_OV	V_{SREG} overvoltage '1' indicates the voltage at V_{SREG} has reached the overvoltage threshold Bit is latched until a "Read and clear" command
2	VSREG_UV	V_{SREG} undervoltage '1' indicates the voltage at V_{SREG} has reached the undervoltage threshold Bit is latched until a "Read and clear" command
1	VS_OV	V_S overvoltage '1' indicates the voltage at V_S has reached the overvoltage threshold Bit is latched until a "Read and clear" command
0	VS_UV	V_S undervoltage '1' indicates the voltage at V_S has reached the undervoltage threshold Bit is latched until a "Read and clear" command

7.5.3 Status Register SR3 (0x33)

Figure 82. Status Register SR3 (0x33)

	23	22	21	20	19	18	17	16	15	14	1	12	11	1	9	8	7	6	5	4	3	2	1	0
Bit name	OUT1_HS_OC_TH_EX	OUT1_LS_OC_TH_EX	OUT2_HS_OC_TH_EX	OUT2_LS_OC_TH_EX	OUT3_HS_OC_TH_EX	OUT3_LS_OC_TH_EX	OUT6_HS_OC_TH_EX	OUT6_LS_OC_TH_EX	OUT7_OC_TH_EX	OUT8_OC_TH_EX	OUT9_OC_STAT	OUT10_OC_STAT	OUT13_OC_STAT	OUT14_OC_STAT	OUT15_OC_TH_EX	Reserved		DSMON_HS2_B	DSMON_HS1_B	DSMON_LS2_B	DSMON_LS1_B	Reserved	LSB_FSO_OC	LSA_FSO_OC
Access	R/C															R		R/C						

Table 117. SR3 signals description

Bit	Name	Description
23	OUT1_HS_OC_TH_EX	Overcurrent shutdown for (OUT1-2-3-6-7-8) '1' indicates the output was shut down due to overcurrent condition. If Overcurrent Recovery is disabled (CR7: OUTx_OCR = 0): Bit is set upon overcurrent condition and output is turned off. If Overcurrent Recovery is enabled (CR7: OUTx_OCR = 1): In case of overcurrent condition this bit is not set. The output goes into Overcurrent Recovery mode and OUTx_OCR_alert in SR4 is set to '1' In case of Thermal Expiration enabled (CR8: OUTx_OCR_THx_en = 1): Bit is set after thermal expiration and output is turned off Bit is latched until a "Read and clear" command
22	OUT1_LS_OC_TH_EX	
21	OUT2_HS_OC_TH_EX	
20	OUT2_LS_OC_TH_EX	
19	OUT3_HS_OC_TH_EX	
18	OUT3_LS_OC_TH_EX	
17	OUT6_HS_OC_TH_EX	
16	OUT6_LS_OC_TH_EX	
15	OUT7_OC_TH_EX	
14	OUT8_OC_TH_EX	
13	OUT9_OC_STAT	Overcurrent shutdown '1' indicates the output was shut down due to overcurrent condition. Bit is latched until a "Read and clear" command
12	OUT10_OC_STAT	
11	OUT13_OC_STAT	
10	OUT14_OC_STAT	
9	OUT15_OC_TH_EX	Overcurrent shutdown for OUT15 '1' indicates the output was shut down due to overcurrent condition. If Overcurrent Recovery is disabled (CR7: OUT15_OCR = 0): Bit is set upon overcurrent condition and output is turned off. If Overcurrent Recovery is enabled (CR7: OUT15_OCR = 1): In case of overcurrent condition this bit is not set. The output goes into Overcurrent Recovery mode and OUT15_OCR_ALERT in SR4 is set to '1' In case of Thermal Expiration enabled (CR8: OUT15_OCR_THX_EN = 1): Bit is set after thermal expiration and output is turned off Bit is latched until a "Read and clear" command
8:7	Reserved	---
6	DSMON_HS2_B	Drain-Source Monitoring for H-bridge B '1' indicates a short-circuit or open-load condition was detected Bit is latched until a "Read and clear" command
5	DSMON_HS1_B	
4	DSMON_LS2_B	
3	DSMON_LS1_B	
2	Reserved	---
1	LSB_FSO_OC	Overcurrent shutdown '1' indicates the output was shut down due to overcurrent condition. Bit is latched until a "Read and clear" command
0	LSA_FSO_OC	Overcurrent shutdown '1' indicates the output was shut down due to overcurrent condition. Bit is latched until a "Read and clear" command

7.5.4 Status Register SR4 (0x34)

Figure 83. Status Register SR4 (0x34)

	23	22	21	20	19	18	17	1	1	14	13	1	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT1_HS_OCR_ALERT	OUT1_LS_OCR_ALERT	OUT2_HS_OCR_ALERT	OUT2_LS_OCR_ALERT	OUT3_HS_OCR_ALERT	OUT3_LS_OCR_ALERT	OUT6_HS_OCR_ALERT	OUT6_LS_OCR_ALERT	OUT7_OCR_ALERT	OUT8_OCR_ALERT	OUT15_OCR_ALERT	Reserved					OUT1_HS_SHORT	OUT1_LS_SHORT	OUT2_HS_SHORT	OUT2_LS_SHORT	OUT3_HS_SHORT	OUT3_LS_SHORT	OUT6_HS_SHORT	OUT6_LS_SHORT
Access	R																R/C							

Table 118. SR4 signals description

Bit	Name	Description
23	OUT1_HS_OCR_ALERT	Auto recovery Alert '1' indicates that the output reached the overcurrent threshold and is in auto recovery mode Bit is not latched and cannot be cleared.
22	OUT1_LS_OCR_ALERT	
21	OUT2_HS_OCR_ALERT	
20	OUT2_LS_OCR_ALERT	
19	OUT3_HS_OCR_ALERT	
18	OUT3_LS_OCR_ALERT	
17	OUT6_HS_OCR_ALERT	
16	OUT6_LS_OCR_ALERT	
15	OUT7_OCR_ALERT	
14	OUT8_OCR_ALERT	
13	OUT15_OCR_ALERT	
12:8	Reserved	--
7	OUT1_HS_SHORT	Short circuit Threshold Alert '1' indicates that the output reached the short circuit threshold Bit is latched and can be cleared with Read&Clear command
6	OUT1_LS_SHORT	
5	OUT2_HS_SHORT	
4	OUT2_LS_SHORT	
3	OUT3_HS_SHORT	
2	OUT3_LS_SHORT	
1	OUT6_HS_SHORT	
0	OUT6_LS_SHORT	

7.5.5 Status Register SR5 (0x35)

Figure 84. Status Register SR5 (0x35)

	23	22	21	20	19	18	17	16	15	14	13	12	1	10	9	8	7	6	5	4	3	2	1	0
Bit name	OUT1_HS_OL	OUT1_LS_OL	OUT2_HS_OL	OUT2_LS_OL	OUT3_HS_OL	OUT3_LS_OL	OUT6_HS_OL	OUT6_LS_OL	OUT7_OL_STAT	OUT8_OL_STAT	OUT9_OL_STAT	OUT10_OL_STAT	OUT13_OL_STAT	OUT14_OL_STAT	OUT15_OL_STAT	GH_OL	ECV_OL	Reserved					DSMON_HEAT	ECV_OC
Access	R/C																	R					R/C	

Table 119. SR5 signals description

Bit	Name	Description
23	OUT1_HS_OL	Open-load '1' indicates an open-load condition was detected at the output Bit is latched until a "Read and clear" command
22	OUT1_LS_OL	
21	OUT2_HS_OL	
20	OUT2_LS_OL	
19	OUT3_HS_OL	
18	OUT3_LS_OL	
17	OUT6_HS_OL	
16	OUT6_LS_OL	
15	OUT7_OL_STAT	
14	OUT8_OL_STAT	
13	OUT9_OL_STAT	
12	OUT10_OL_STAT	
11	OUT13_OL_STAT	
10	OUT14_OL_STAT	
9	OUT15_OL_STAT	
8	GH_OL	
7	ECV_OL	
6:2	Reserved	--
1	DSMON_HEAT	Drain-Source Monitoring Heater output '1' indicates a short-circuit condition was detected Bit is latched until a "Read and clear" command
0	ECV_OC	Overcurrent shutdown '1' indicates the output was shut down due to overcurrent condition. Bit is latched until a "Read and clear" command

7.5.6 Status Register SR6 (0x36)

Figure 85. Status Register SR6 (0x36)

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	WD_TIMER_STATE_1	WD_TIMER_STATE_0	Reserved				ECV_VNR	ECV_VHI	Reserved		TW_CL6	TW_CL5	TW_CL4	TW_CL3	TW_CL2	TW_CL1	Reserved		TSD1_CL6	TSD1_CL5	TSD1_CL4	TSD1_CL3	TSD1_CL2	TSD1_CL1
Access	R		R/C				R		R/C															

Table 120. SR6 signals description

Bit	Name	Description
23	WD_TIMER_STATE_1	Watchdog timer status 00: 0 - 33% 01: 33 - 66% 11: 66 - 100%
22	WD_TIMER_STATE_0	
21:18	Reserved	—
17	ECV_VNR	Electrochrome Voltage Not Reached: electrochrome voltage status '1' indicates the electrochrome voltage is not reached. Bit is not latched
16	ECV_VHI	Electrochrome Voltage HIgh: electrochrome voltage status '1' indicates the electrochrome voltage is higher than the target value. Bit is not latched
15:14	Reserved	—
13	TW_CL6	Thermal warning for Cluster x ‘1’ indicates Cluster x has reached the thermal warning threshold Bit is latched until a “Read and clear” command
12	TW_CL5	
11	TW_CL4	
10	TW_CL3	
9	TW_CL2	
8	TW_CL1	
7:6	Reserved	—

Table 120. SR6 signals description (continued)

Bit	Name	Description
5	TSD1_CL6	Thermal shutdown of Cluster x '1' indicates Cluster x has reached the thermal shutdown threshold (TSD1) and the output cluster was shut down Bit is latched until a "Read and clear" command
4	TSD1_CL5	
3	TSD1_CL4	
2	TSD1_CL3	
1	TSD1_CL2	
0	TSD1_CL1	

7.5.7 Status Register SR7 (0x37) to SR9 (0x39)

Figure 86. Status Register SR7 (0x37) to SR9 (0x39)

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved		TEMP_CLx_9	TEMP_CLx_8	TEMP_CLx_7	TEMP_CLx_6	TEMP_CLx_5	TEMP_CLx_4	TEMP_CLx_3	TEMP_CLx_2	TEMP_CLx_1	TEMP_CLx_0	Reserved		TEMP_CLy_9	TEMP_CLy_8	TEMP_CLy_7	TEMP_CLy_6	TEMP_CLy_5	TEMP_CLy_4	TEMP_CLy_3	TEMP_CLy_2	TEMP_CLy_1	TEMP_CLy_0
Access	R/C		R										R/C		R									

where:

x = 2 + (z * 2), z = 0 to 2

y = 1 + (z * 2), z = 0 to 2

Table 121. SR7 to SR9 signals description

Bit	Name	Description
23:22	Reserved	—
21	TEMP_CLx_9	Temperature Cluster x: Binary coded voltage of temperature diode for cluster x (bit12 = LSB; bit21 = MSB) (see *Section 4.37*) Bits cannot be cleared.
20	TEMP_CLx_8	
19	TEMP_CLx_7	
18	TEMP_CLx_6	
17	TEMP_CLx_5	
16	TEMP_CLx_4	
15	TEMP_CLx_3	
14	TEMP_CLx_2	
13	TEMP_CLx_1	
12	TEMP_CLx_0	
11:10	Reserved	—

Table 121. SR7 to SR9 signals description (continued)

Bit	Name	Description
9	TEMP_CLy_9	Temperature Cluster y: binary coded voltage of temperature diode for cluster y (bit0 = LSB; bit9 = MSB) (see *Section 4.37*) Bits cannot be cleared.
8	TEMP_CLy_8	
7	TEMP_CLy_7	
6	TEMP_CLy_6	
5	TEMP_CLy_5	
4	TEMP_CLy_4	
3	TEMP_CLy_3	
2	TEMP_CLy_2	
1	TEMP_CLy_1	
0	TEMP_CLy_0	

7.5.8 Status Register SR10 (0x3A)

Figure 87. Status Register SR10 (0x3A)

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved		VSREG_9	VSREG_8	VSREG_7	VSREG_6	VSREG_5	VSREG_4	VSREG_3	VSREG_2	VSREG_1	VSREG_0	Reserved											
Access	R/C		R										R/C											

Table 122. SR10 signals description

Bit	Name	Description
23:22	Reserved	—
21	VSREG_9	Binary coded voltage at V_{SREG} pin (bit12 = LSB; bit21 = MSB) 00 0000 0000: 0V xx xxxx xxxx: VAINVS/1024 x register value 11 1111 1111: VAINVS Bits cannot be cleared.
20	VSREG_8	
19	VSREG_7	
18	VSREG_6	
17	VSREG_5	
16	VSREG_4	
15	VSREG_3	
14	VSREG_2	
13	VSREG_1	
12	VSREG_0	
11:0	Reserved	—

7.5.9 Status Register SR11 (0x3B)

Figure 88. Status Register SR11 (0x3B)

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved		VS_9	VS_8	VS_7	VS_6	VS_5	VS_4	VS_3	VS_2	VS_1	VS_0	Reserved		VWU_9	VWU_8	VWU_7	VWU_6	VWU_5	VWU_4	VWU_3	VWU_2	VWU_1	VWU_0
Access	R/C		R										R/C		R									

Table 123. SR11 signals description

Bit	Name	Description
23	Reserved	—
21	VS_9	Binary coded voltage at Vs pin (bit12 = LSB; bit21 = MSB) 00 0000 0000: 0V xx xxxx xxxx: V_{AINVS}/1023 x register value 11 1111 1111: V_{AINVS} Bits cannot be cleared.
20	VS_8	
19	VS_7	
18	VS_6	
17	VS_5	
16	VS_4	
15	VS_3	
14	VS_2	
13	VS_1	
12	VS_0	
11:10	Reserved	—
9	VWU_9	Binary coded voltage at WU pin (bit0 = LSB; bit9 = MSB) 00 0000 0000: 0V xx xxxx xxxx: V_{AINVS}/1023 x register value 11 1111 1111: V_{AINVS} Bits cannot be cleared.
8	VWU_8	
7	VWU_7	
6	VWU_6	
5	VWU_5	
4	VWU_4	
3	VWU_3	
2	VWU_2	
1	VWU_1	
0	VWU_0	

7.5.10 Status Register SR12 (0x3C)

Figure 89. Status Register SR12 (0x3C)

	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Bit name	Reserved																		CAN_SILENT	Reserved	CANTO	WUP	Reserved	
Access	R																							

Table 124. SR12 signals description

Bit	Name	Description
23:6	Reserved	—
5	CAN_SILENT	Online monitoring bit to see if there is silence on the bus for longer than $t_{Silence}$ This flag shows the actual status of the CAN bus (activity/silence). A microcontroller in Stop mode may check this flag periodically
4	Reserved	--
3	CANTO	CAN communication timeout Bit is set if there is no communication on the bus for t > $t_{Silence}$ CANTO indicates that there was a transition from TRX BIAS to TRX Sleep Bit is latched until a read and clear access
2	WUP	Wake up flag for Wake up Pattern Bit is latched until a read and clear access
1:0	Reserved	--

8 Package information

In order to meet environmental requirements, ST offers these devices in different grades of *ECOPACK* packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK is an ST trademark.

8.1 LQFP-64 package information

Figure 90. LQFP-64 package dimension

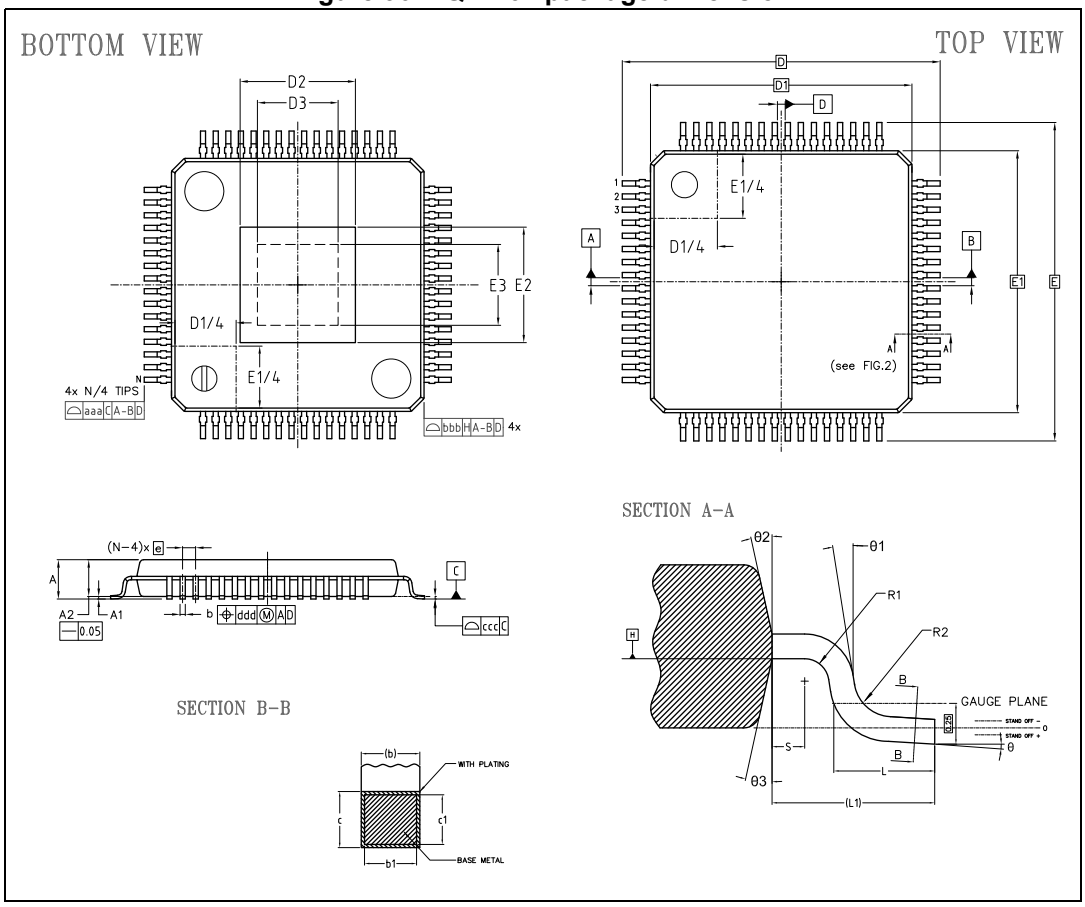


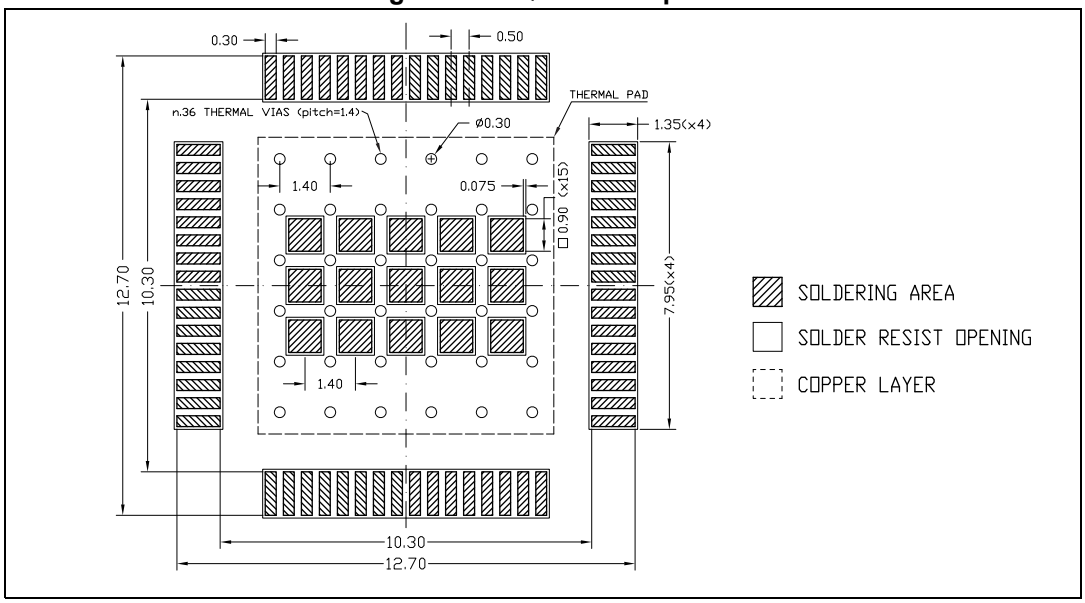
Table 125. LQFP-64 mechanical data

Symbol	Millimeters/Degrees		
	Min.	Typ.	Max.
Θ	0º	3.5°	6°
Θ1	0º	9°	12°
Θ2	11º	12°	13°
Θ3	11º	12°	13°

Table 125. LQFP-64 mechanical data (continued)

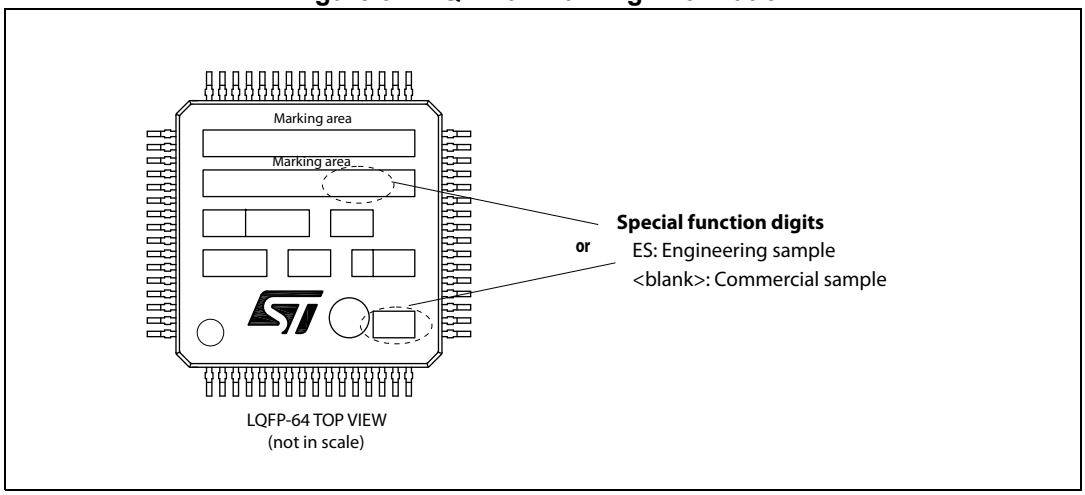
Symbol	Millimeters/Degrees		
	Min.	Typ.	Max.
A			1.60
A1	0.05		0.15
A2	1.35	1.40	1.45
b			0.27
b1	0.17	0.20	0.23
c	0.09		0.20
c1	0.09	0.127	0.16
D	12.00 BSC		
D1	10.00 BSC		
D2			6.85
D3	5.7		
e	0.50 BSC		
E	12.00 BSC		
E1	10.00 BSC		
E2			4.79
E3	3.3		
L	0.45	0.60	0.75
L1	1.00		
N	64		
R1	0.08		
R2	0.08		0.20
S	0.20		
Tolerance of form and position			
aaa	0.20		
bbb	0.20		
ccc	0.08		
ddd	0.08		

Figure 91. LQFP-64 footprint



8.2 LQFP-64 marking information

Figure 92. LQFP-64 marking information



Parts marked as ES are not yet qualified and therefore not approved for use in production. ST is not responsible for any consequences resulting from such use. In no event will ST be liable for the customer using any of these engineering samples in production. ST's Quality department must be contacted to run a qualification activity prior to any decision to use these engineering samples.

9 Order code

Table 126. Ordering information

Package	Order codes	
	Tape & Reel	Tray
LQFP-64 epad	L99DZ200GTR	L99DZ200G

10 Revision history

Table 127. Document revision history

Date	Revision	Changes
16-Jan-2020	1	Initial release.
08-Oct-2020	2	Updated: – *Figure 3: Activation profile*; – *Figure 4: Activation profile (first cycle)*; – *Figure 7: Watchdog timing* – *Figure 19: Sequence to disable/enable the watchdog in CAN Flash mode*; – *Figure 61: Typical application diagram*; – *Table 112: CR21 signals description* . Minor text changes.
23-Nov-2020	3	Updated *Table 5: Temperature Warning and Thermal Shutdown*, *Table 10: Voltage regulator V1*, *Table 18: Power outputs switching times*, *Table 19: Current monitoring*, *Table 27: Electro-chrome mirror driver*, *Figure 61: Typical application diagram*, *Table 122: SR10 signals description*, *Table 123: SR11 signals description*.
26-Mar-2021	4	Updated: – *Features* – *Table 3: ESD protection* – *Section 4.9.1: Features* – *Section 4.10.1: Features* – Add *Section 9: Order code* Changed *Figure 61*
06-Apr-2021	5	Typos.

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