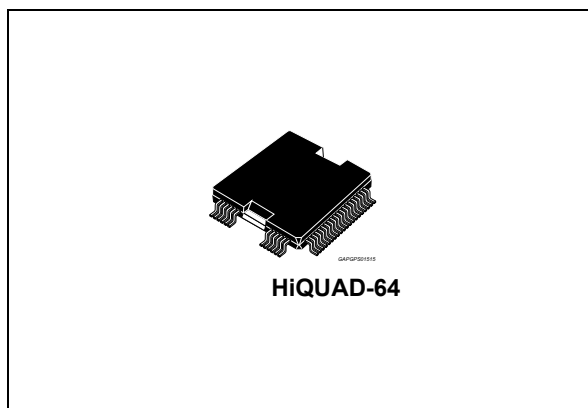


## Multifunction IC for engine management system

Datasheet - production data



### Features

- 5 V logic regulator
- 3.3 V logic regulator
- 5 V tracking sensor supply
- Smart reset function
- Power latch with Secure Engine Off (SEO) functionality, to safely complete driver switch off procedure
- Flying wheel interface function (VRS) with adaptive time and amplitude control
- Protected low-side relay driver
  - OUT13 to 18, MRD
- Protected low-side (injector drivers)
  - OUT1 to 4

- Protected low-side (high current)
  - OUT5, 6, 7
- Protected low-side (low current)
  - OUT20
- IGBT pre-drivers (IGN1 to 4) with parallel input
- Parallel input IN1 to IN7 to drive OUT1 to OUT7
- Configurable power stages CPS
  - Stepper motor driver/ high-side - low-side (OUTA to D)
- Thermal warning and shutdown
- Serial interface
  - SPI 16-bit frame
  - ISO9141 interface (K-Line)
- High speed CAN transceiver
- VDA 2.0 compliance with 3 level Watchdog
- Package: HiQUAD-64

### Description

The L9779WD-SPI is an integrated circuit designed for automotive environment and implemented in BCD6S technology.

It is conceived to provide all basic functions for standard engine management control units.

It is assembled in the HiQUAD-64 power package.

**Table 1. Device summary**

| Order code     | Package   | Packing       |
|----------------|-----------|---------------|
| L9779WD-SPI    | HiQUAD-64 | Tray          |
| L9779WD-SPI-TR | HiQUAD-64 | Tape and Reel |

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# 1 Detailed features description

- Package
  - HiQUAD-64
- 5 V logic regulator
  - 5 V precision voltage regulator ( $\pm 2\%$ ) with external NMOS
  - Max current regulated: 400 mA
  - Charge pump capacitor at pin CP is used to drive the gate of the external NMOS transistor
- 3.3 V logic regulator
  - 3.3 V precision voltage regulator ( $\pm 2\%$ ) with over-current protection
  - Max current regulated: 100 mA
- 5 V tracking sensor supply
  - 2 x 5 V tracking sensor supply with protection and diagnosis on SPI
  - Short-circuit to Vbat/GND fully protected
  - Max current regulated: 2 x 100 mA
- Smart reset
  - Main Reset monitoring VB\_UV Logic voltage management and safety control
- Watch dog
  - Main reset management 5 V voltage monitoring safety output disable
  - SPI controllable query and answer watch dog compliant with VDA2.0 level 3 (enabled by default)
- Power latch
  - L9779WD-SPI is switched on by KEY\_ON signal and switched off by logic OR of KEY\_ON signal and SPI bit
- Secure engine off mode (default) switches off the drivers in the following order:
  - OUT1 through to OUT4 in 225 ms (typical)
  - OUT13 and OUT14 in 600 ms (typical)
- Flying wheel interface function (VRS)
  - The VRS is the interface between the microprocessor and the magnetic pick-up or variable reluctance sensor that collects the information coming from the flying wheel
  - Adaptive filtering on amplitude and timing adapts better the device response to VRS input switching
- Protected low-side driver
  - LSa (OUT1 to 5)
    - 4 Ch. serial IN via SPI and parallel IN,  $R_{dson} = 0.72 \text{ Ohm @}150^\circ\text{C}$ ,  $V_{cl} = 58 \text{ V } \pm 5$ ,  $I_{max} = 2.2 \text{ A}$ ;
    - 1 Ch. serial IN via SPI and parallel IN,  $R_{dson} = 0.72 \text{ Ohm @}150^\circ\text{C}$ ,  $V_{cl} = 58 \text{ V } \pm 5$ ,  $I_{max} = 3 \text{ A}$ ;
  - LSb (OUT6, 7)
    - 2 Ch. serial IN via SPI and parallel IN,  $R_{dson} = 0.47 \text{ Ohm @}150^\circ\text{C}$ ,  $V_{cl} = 45 \text{ V } \pm 5$ ,  $I_{max} = 5 \text{ A}$

Full diagnosis on SPI (2 bit for each channel) and voltage slew rate control.

When an over current fault occurs, the driver switches off with faster slew rate in order to reduce the power dissipation.

- LSc (OUT20)
  - 1 Ch serial IN via SPI,  $I_{max} = 50 \text{ mA}$

- LSD (OUT13 to 18, MRD)

6 Ch. serial IN via SPI,  $R_{dson} = 1.5 \text{ Ohm @ } 150 \text{ }^\circ\text{C}$ ,  $V_{cl} = 48 \text{ V}$ ,  $I_{max} = 600 \text{ mA}$  (2 of them with low battery voltage function);

1 main relay driver  $R_{dson} = 2.4 \text{ Ohm @ } 150 \text{ }^\circ\text{C}$ ,  $V_{cl} = 48 \text{ V}$ ,  $I_{max} = 600 \text{ mA}$

With full diagnosis on SPI (2 bit for each channel) and voltage slew-rate control.

When an over current fault occurs, the driver switches off with faster slew rate in order to reduce the power dissipation.

- Ignition pre-drivers (IGN1 to 4) with parallel input
  - 4 x ignition pre-drivers with full diagnostic.
- SPI
- 1 x Stepper motor driver designed for a double winding coil motor, used for engine idle speed control.

The stepper driver is made by 4 independent half bridgeS each one with:

- 1 high-side driver,  $R_{dson} = 1.5 \text{ Ohm}$ ,  $I_{max} = 600 \text{ mA}$
- 1 low-side driver,  $R_{dson} = 1.5 \text{ Ohm}$ ,  $I_{max} = 600 \text{ mA}$

The low-side drivers could be connected in parallel.

Low-side and high-side drivers implement voltage SR control to minimize emission.

Two high-side drivers have the low battery voltage function.

- Thermal shutdown
  - 1 x Thermal shutdown ( $T_j > 175 \text{ }^\circ\text{C} = T_{sd}$ ) if  $T_j > T_{sd}$ : VTRK1, 2 are turned off.
  - 1 x Thermal shutdown ( $T_j > 175 \text{ }^\circ\text{C} = T_{sd}$ ) if  $T_j > T_{sd}$ : OUT1 to 10, OUT13 to 20, OUTA to D, IGN1 to 4 are turned off.
  - 1 x Thermal Shutdown ( $T_j > 175 \text{ }^\circ\text{C} = T_{sd}$ ) if  $T_j > T_{sd}$ : V3V3 is turned off.
  - 1 x Thermal shutdown ( $T_j > 175 \text{ }^\circ\text{C} = T_{sd}$ ) if  $T_j > T_{sd}$ : MRD is turned off (if battery present).

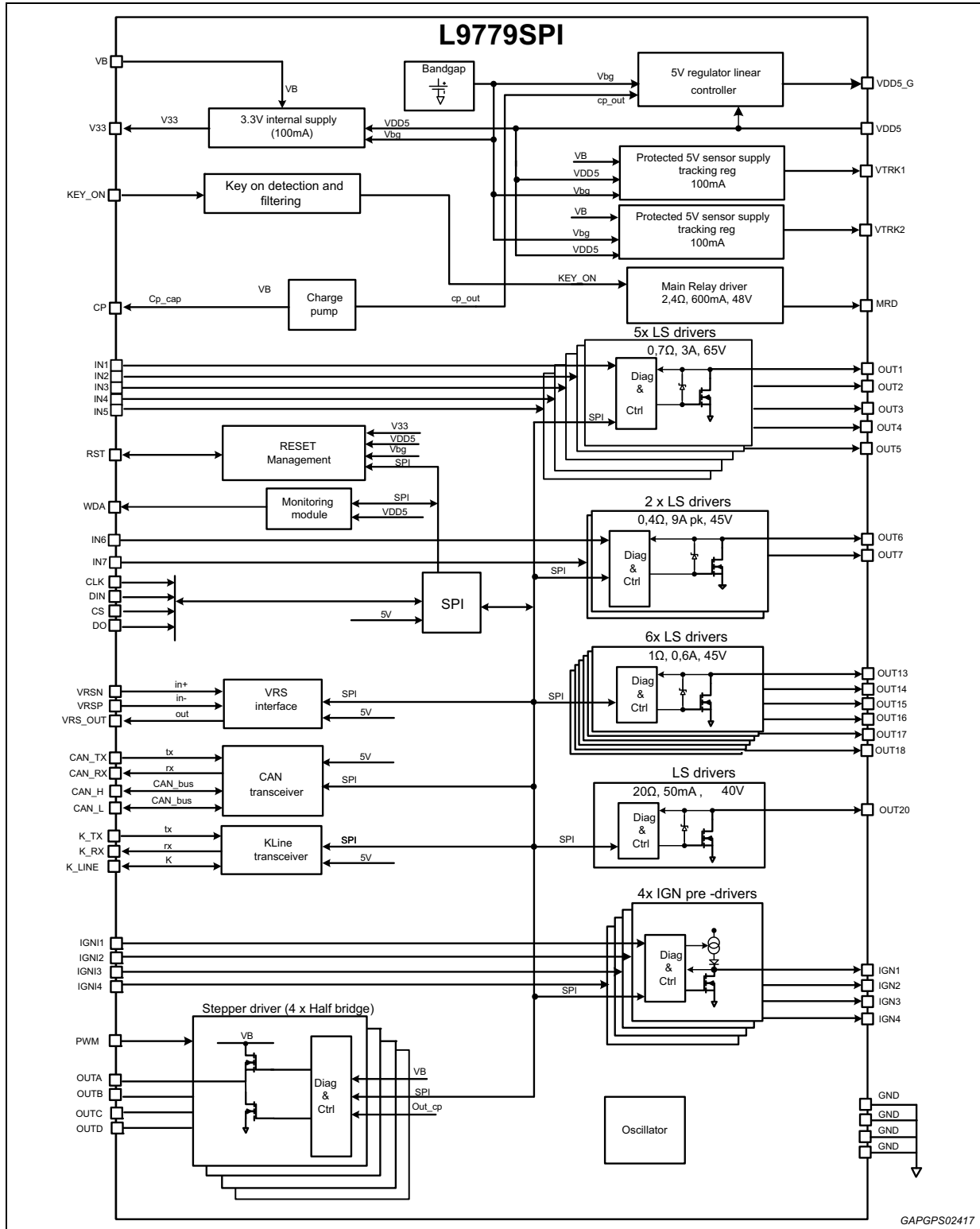
There are 5 temperature sensors for OT2 (OUT1..10, OUT13...20, OUT21...28, IGN1...4 are turned off) in different Layout position, they are logically "AND" in case of thermal shutdown.

- ISO9141 interface
  - ISO9141 serial interface (K-Line)
- CAN transceiver

The CAN bus transceiver allows the connection of the microcontroller, with CAN controller unit, to a high speed CAN bus with transmission rates up to 1Mbit/s for exchange of data with other ECUs.

# 2 Block diagram

Figure 1. Block diagram



### 3 Pins description

Figure 2. Pins connection diagram (top view)

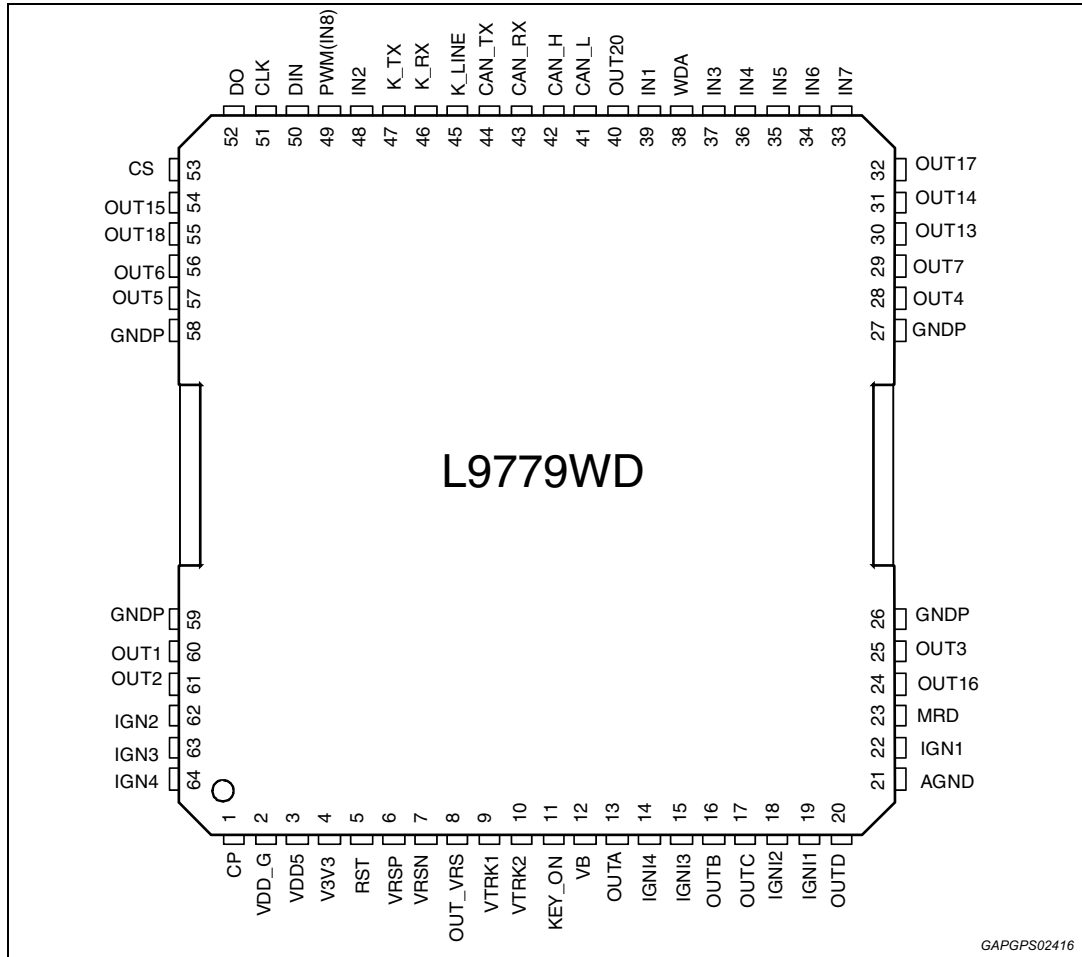


Table 2. Pins description

| Pin#                | Name   | Function                     | Type                                       | Polarization/note |
|---------------------|--------|------------------------------|--|-------------------|
| <b>Supply block</b> |        |                              |  |                   |
| 12                  | VB     | Battery supply               | Power supply polarization                  | -                 |
| 3                   | VDD5   | 5 V output voltage regulator | Power logic output supply                  | -                 |
| 2                   | VDD_G  | 5 V regulator ext MOS gate   | Analog output                              | -                 |
| 11                  | KEY_ON | Key signal                   | Analog Input protected with 20 kΩ resistor | PD 100 kΩ         |

Table 2. Pins description (continued)

| Pin#                    | Name    | Function                                   | Type                         | Polarization/note                            |
|-------------------------|---------|--|------------------------------|--|
| 4                       | V3V3    | 3.3 V output voltage regulator             | Power logic output supply    | -  |
| 1                       | CP      | Charge Pump                                | Analog Input                 | -  |
| 9                       | VTRK1   | Sensor1 tracking supply 5V                 | Sensor supply output         | -  |
| 10                      | VTRK2   | Sensor1 tracking supply 5 V                | Sensor supply output         | -  |
| 5                       | RST     | Reset output for $\mu$ P                   | DGT output                   | Open drain $10k\Omega > PU > 1k\Omega^{(1)}$ |
| 38                      | WDA     | WDA Interrupt Signal                       | Output: open drain DGT input | -  |
| <b>VRS</b>              |         |  |                              |  |
| 7                       | VRSN    | Negative VRS input                         | Analog Input                 | 1.65 V Internal polarization                 |
| 6                       | VRSP    | Positive VRS input                         | Analog Input                 | 1.65 V Internal polarization                 |
| 8                       | OUT_VRS | Digital VRS output                         | DGT Output                   | Open drain                                   |
| <b>CAN</b>              |         |  |                              |  |
| 44                      | CAN_TX  | Can transceiver input (from TX $\mu$ P)    | DGT Input                    | -  |
| 43                      | CAN_RX  | Can transceiver output (to RX $\mu$ P)     | DGT Output                   | -  |
| 42                      | CAN_H   | Bi-dir protected CAN_H wire                | Analog Input/Output          | -  |
| 41                      | CAN_L   | Bi-dir protected CAN_L wire                | Analog Input/Output          | -  |
| <b>ISO9141</b>          |         |  |                              |  |
| 47                      | K_TX    | ISO9141 logical input                      | DGT Input                    | $I_{Pu} = 20 \mu A$                          |
| 45                      | K_LINE  | Bi-dir protected K-line wire               | Analog Input/Output          | Open drain                                   |
| 46                      | K_RX    | ISO9141 logical output                     | DGT Output                   | Open drain                                   |
| <b>Low side drivers</b> |         |  |                              |  |
| 60                      | OUT1    | Output low-side 1 for R , L Load(Injector) | Power output                 | Open drain                                   |
| 61                      | OUT2    | Output low-side 2 for R , L Load(Injector) | Power output                 | Open drain                                   |
| 25                      | OUT3    | Output low-side 3 for R , L Load(Injector) | Power output                 | Open drain                                   |

Table 2. Pins description (continued)

| Pin#                               | Name  | Function                                       | Type         | Polarization/note |
|------------------------------------|-------|--|--------------|-------------------|
| 28                                 | OUT4  | Output low-side 4 for R, L Load(Injector)      | Power output | Open drain        |
| 26                                 | PGND3 | Power GND                                      | PGND1        | -                 |
| 27                                 | PGND4 | Power GND                                      | PGND2        | -                 |
| 57                                 | OUT5  | Output low-side 5 for R , L Load(High current) | Power output | Open drain        |
| 56                                 | OUT6  | Output low-side 6 for R , L Load(Heater)       | Power output | Open drain        |
| 29                                 | OUT7  | Output low-side 7 for R , L Load(Heater)       | Power output | Open drain        |
| 30                                 | OUT13 | Output low-side 13 for Relay                   | Power output | Open drain        |
| 31                                 | OUT14 | Output low-side 14 for relay                   | Power output | Open drain        |
| 54                                 | OUT15 | output low-side 15 for relay                   | Power output | Open drain        |
| 24                                 | OUT16 | Output low-side 16 for relay                   | Power output | Open drain        |
| 32                                 | OUT17 | Output low-side 17 for relay                   | Power output | Open drain        |
| 55                                 | OUT18 | Output low-side 18 for relay                   | Power output | Open drain        |
| 58                                 | PGND3 | Power GND                                      | PGND3        | -                 |
| 59                                 | PGND4 | Power GND                                      | PGND4        | -                 |
| <b>IGBT pre-driver</b>             |       |  |              |                   |
| 22                                 | IGN1  | Output ignition driver 1                       | Power output | -                 |
| 62                                 | IGN2  | Output ignition driver 2                       | Power output | -                 |
| 63                                 | IGN3  | Output ignition driver 3                       | Power output | -                 |
| 64                                 | IGN4  | Output ignition driver 4                       | Power output | -                 |
| <b>Main relay driver</b>           |       |  |              |                   |
| 23                                 | MRD   | Main relay driver                              | Power output | Open drain        |
| <b>Low current drivers (50 mA)</b> |       |  |              |                   |
| 40                                 | OUT20 | Output low-side 20                             | Power output | Open drain        |
| <b>Parallel input</b>              |       |  |              |                   |
| 39                                 | IN1   | Parallel input for OUT1                        | DGT Input    | -                 |
| 48                                 | IN2   | Parallel input for OUT2                        | DGT Input    | -                 |
| 37                                 | IN3   | Parallel input for OUT3                        | DGT Input    | -                 |
| 36                                 | IN4   | Parallel input for OUT4                        | DGT Input    | -                 |
| 35                                 | IN5   | Parallel input for OUT5                        | DGT Input    | -                 |
| 34                                 | IN6   | Parallel input for OUT6                        | DGT Input    | -                 |

Table 2. Pins description (continued)

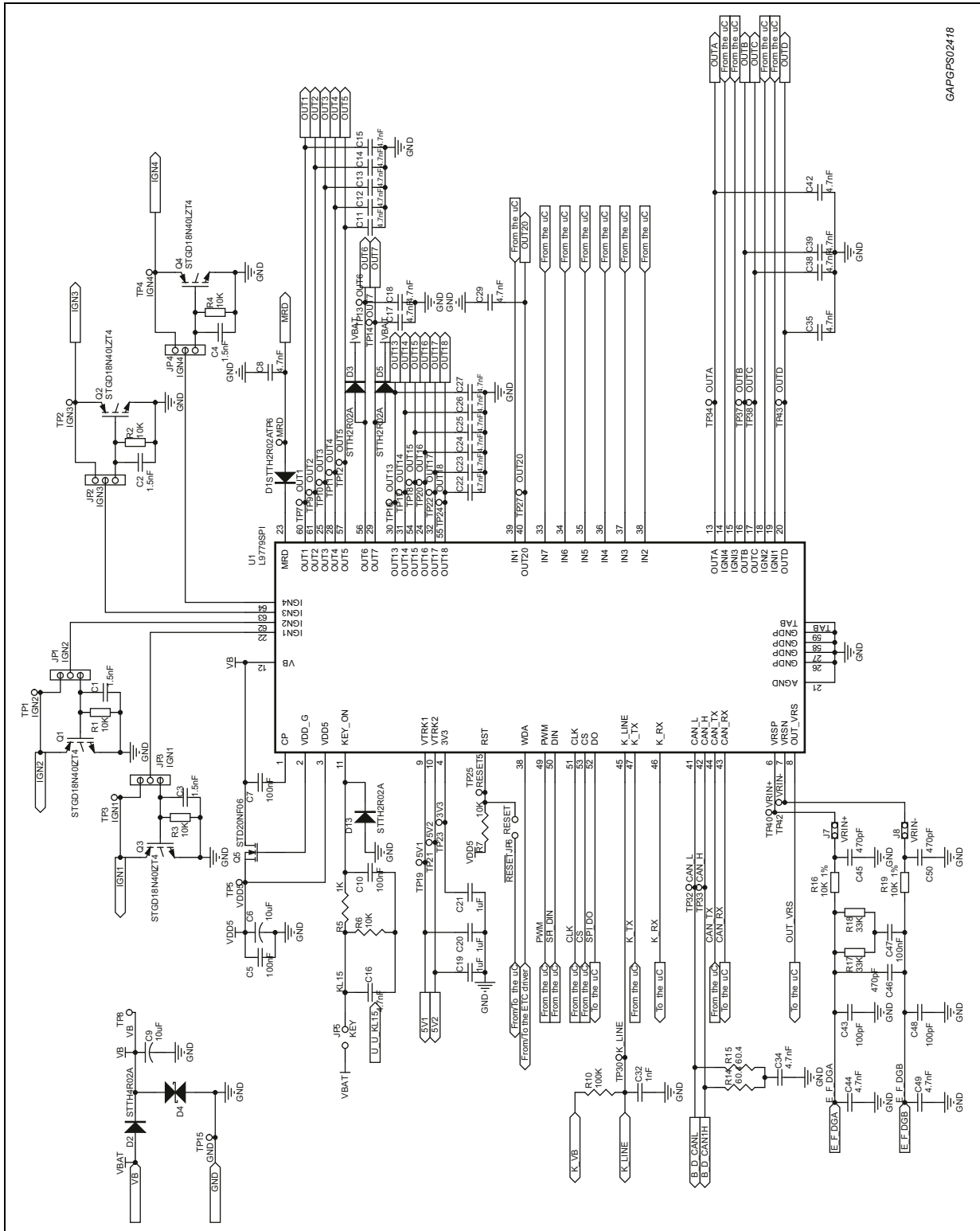
| Pin#                        | Name      | Function                            | Type         | Polarization/note |
|-----------------------------|-----------|-------------------------------------|--------------|-------------------|
| 33                          | IN7       | Parallel input for OUT7             | DGT Input    | -                 |
| 49                          | PWM (IN8) | PWM input for stepper motor driving | DGT Input    | -                 |
| 19                          | IGNI1     | Parallel input for IGN1             | DGT Input    | -                 |
| 18                          | IGNI2     | Parallel input for IGN2             | DGT Input    | -                 |
| 15                          | IGNI3     | Parallel input for IGN3             | DGT Input    | -                 |
| 14                          | IGNI4     | Parallel input for IGN4             | DGT Input    | -                 |
| <b>SPI interface</b>        |           |                                     |              |                   |
| 51                          | SCK       | SPI clock input                     | DGT Input    | -                 |
| 53                          | CS        | SPI chip select                     | DGT Input    | -                 |
| 50                          | DIN       | SPI data input                      | DGT Input    | -                 |
| 52                          | DO        | SPI data output                     | DGT Output   | -                 |
| <b>Stepper motor driver</b> |           |                                     |              |                   |
| 13                          | OUTA      | Stepper                             | Power output | -                 |
| 16                          | OUTB      | Stepper                             | Power output | -                 |
| 17                          | OUTC      | Stepper                             | Power output | -                 |
| 20                          | OUTD      | Stepper                             | Power output | -                 |
| 21                          | GND       | Stepper GND                         | GND          | -                 |

1. External components required.

*Note:* OUT11 and OUT12 are not valid.

# 4 Application schematic

Figure 3. Application schematic



GAPGPS02418





## 5 Absolute maximum ratings

**Warning:** Maximum ratings are absolute ratings: exceeding any of these values may cause permanent damage to the integrated circuit

**Table 3. Absolute maximum ratings**

| Pin      | Parameter                            | Condition   | Value  | Unit |
|----------|--------------------------------------|---|--|------|
| VB       | DC supply battery power voltage (Vb) | Also without external components  | -0.3 to +40                                  | V    |
| V3V3     | DC logic supply voltage              | -   | -0.3 to VDD5, when V3V3 = VDD5 = 19 V max    | V    |
| VTRK1,2  | DC sensors supply voltage            | -   | -2 to +40                                    | V    |
| VDD_G    | -                                    | -   | -0.3 to VDD5, when VDDG = VDD5 = 19 V max    | V    |
| VDD5     | Voltage pin                          | -   | -0.3 to 19                                   | V    |
| CP       | -                                    | -   | -0.3 to 40<br>Max ABS = +40 V when VB = 40 V | V    |
| KEY_ON   | -                                    | Protected with external component (R = 1 k $\Omega$ plus a diode, refer to <a href="#">Figure 4</a> ) for negative pulse (isopulse 1) | -1.2 to +40                                  | V    |
| RST      | -                                    | -   | -0.3 to +19                                  | V    |
| VRSP     | -                                    | Max current to be limited with external resistors (see <a href="#">Section 6.14.3: Application circuits on page 93</a> )              | -20 to +20                                   | mA   |
| VRSM     | -                                    | Max current to be limited with external resistors (see <a href="#">Section 6.14.3: Application circuits on page 93</a> )              | -20 to +20                                   | mA   |
| MRD      | -                                    | -   | -0.3 to +40                                  | V    |
| OUT1-5   | Low-side output                      | -   | -1 to +53                                    | V    |
| OUT6-7   | Low-side output                      | -   | -1 to +40                                    | V    |
| OUT13-18 | Low-side output                      | -   | -1 to +40                                    | V    |
| OUT20    | Low-side output                      | -   | -1 to +40                                    |      |
| IGNx     | -                                    | -   | -1 to 19                                     | V    |

**Table 3. Absolute maximum ratings (continued)**

| Pin  | Parameter          | Condition  | Value   | Unit |
|--|--------------------|--|---|------|
| OUTA, OUTB, OUTC, OUTD   | Half bridge output | With external diode vs ground for negative voltage | -1.0 to VB<br>(-2.0 dynamically for a short time) | V    |
| DO, CAN_RX, K_RX, OUT_VRS  | -                  | -  | -0.3 to VDD_IO, when DO = VDD_IO = 19 V max       | V    |
| CS, CLK, DIN, IN1, IN2, IN3, IN4, IN5, IN6, IN7, PWM, IGN1, IGN2, IGN3, IGN4 | -                  | -  | -0.3 to +19                                       | V    |
| CAN_TX   | -                  | -  | -0.3 to +19                                       | V    |
| CAN_H, CAN_L   | -                  | -  | -18 to 40   | V    |
| K_TX   | -                  | -  | -0.3 to +19                                       | V    |
| K_LINE   | -                  | -  | -18 to 40   | V    |

### 5.1 ESD protection

**Table 4. ESD protection**

| Item                             | Condition   | Min  | Max  | Unit |
|----------------------------------|---|------|------|------|
| All pins                         | Electro static discharge voltage "Charged-device-model – CDM" all pin <sup>(1)</sup>              | -500 | +500 | V    |
| All pins                         | Electro static discharge voltage "Charged-device-model – CDM" corner pin (1,20,21,32,33,52,53,64) | -750 | +750 | V    |
| All pins                         | ESD voltage HBM respect to GND  | -2   | +2   | KV   |
| Pins to connector <sup>(2)</sup> | ESD voltage HBM respect to GND  | -4   | +4   | KV   |

1. Except OUTA, B, C, D ±250 V.

2. Pins are LSa, LSb, LSc, LSd, IGNx, VTRK1-2, CAN\_H, CAN\_L, K\_LINE, OUTA, B, C, D.

Test circuit according to HBM (EIA/JESD22-A114-B) and CDM (EIA/JESD22-C101-C).

## 5.2 Latch-up test

According to JEDEC 78 class 2 level A.

## 5.3 Temperature ranges and thermal data

Table 5. Temperature ranges and thermal data

| Symbol         | Parameter   | Min | Max | Unit |
|----------------|---|-----|-----|------|
| $T_{amb}$      | Operating temperature                                     | -40 | 125 | °C   |
| $T_j$          | Continuative operative junction temperature               | -40 | 150 | °C   |
| $T_{stg}$      | Storage temperature                                       | -40 | 150 | °C   |
| $R_{thj-case}$ | Thermal resistance junction-to-case                       | -   | 1   | °C/W |
| $R_{thj-amb}$  | Thermal resistance junction-to-ambient <sup>(1)</sup>     | -   | 16  | °C/W |
| $T_s$          | Lead temperature during soldering (for a time = 10 s max) | -   | 260 | °C   |

1. With 2S2P+vias PCB.

## 5.4 Operating range

Table 6. Operating range

| Pins symbol | Battery voltage range   | Junction temperature condition | Note           |
|-------------|---|--------------------------------|----------------|
| VB          | $4.15\text{ V} < V_b < 6\text{ V}$  | $-40 < T_j < 40$               | Low battery    |
|             | $6\text{ V} < V_b = 18\text{ V}$  | $-40 < T_j < 150$              | Normal battery |
|             | $18\text{ V} < V_b = 28\text{ V}$   | $-40 < T_j < 40$               | High battery   |
|             | $28 < V_b = 40\text{ V}$ , $t_{rise} = 10\text{ms}$ , $T_{pulse} = 400\text{ ms}$ . | $-40 < T_j < 40$               | Load dump      |

### 5.4.1 Low battery

All the functions are guaranteed with degraded parameters. The voltage regulators follow VB in RDSon mode with drop-out depending on load current. V3V3 regulator works as expected assuming  $V_{DD5} > 4\text{ V}$ .

### 5.4.2 Normal battery

All the functions and the parameters are guaranteed by testing coverage.

### 5.4.3 High battery

All the functions are guaranteed with degraded parameters.

### 5.4.4 Load dump

The device is switched-off if load dump exceeds battery overvoltage threshold for a time longer than filter time.

## 6 Functional description

### 6.1 Ignition switch, main relay, battery pin

The system has an ignition switch pin KEY\_ON and a pin VB for battery behind the main relay connected at pin MRD.

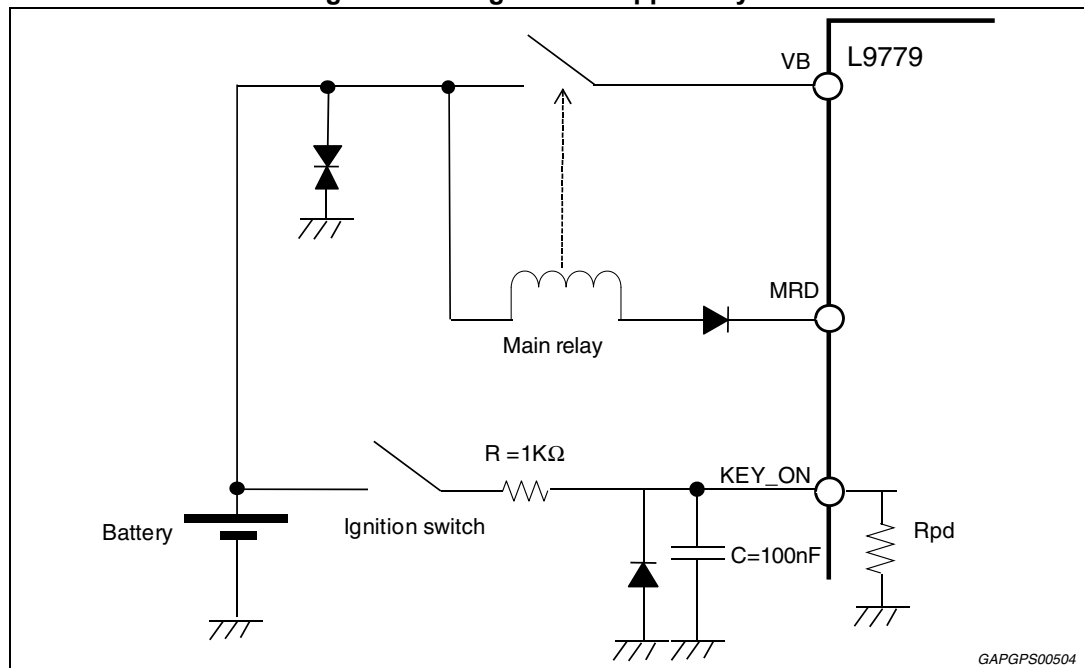
L9779WD-SPI can also support the configuration where it is permanently supplied by VB; in this case the MRD output can be used to connect the loads to VB.

At pin KEY\_ON there is an external diode for reverse battery protection. An internal Pull-down resistor is provided on the KEY\_ON pin. The external components to be connected to KEY pin are shown in the below schematic.

Internal functions and regulators are supplied by VB; only some basic functions required for startup are supplied from KEY\_ON as described below. Reverse protection for pin VB is done by the main relay. Transient negative voltage at VB may be limited by an external diode if necessary. There is no integrated reverse protection at pin VB.

The pin connected to the battery line can bear the ISO 7637/1 noise pulses without any damage. The VB voltage must be externally limited to +40 V and -0.3 V (with external components as in [Figure 4](#)). It is suggested the use of a transil.

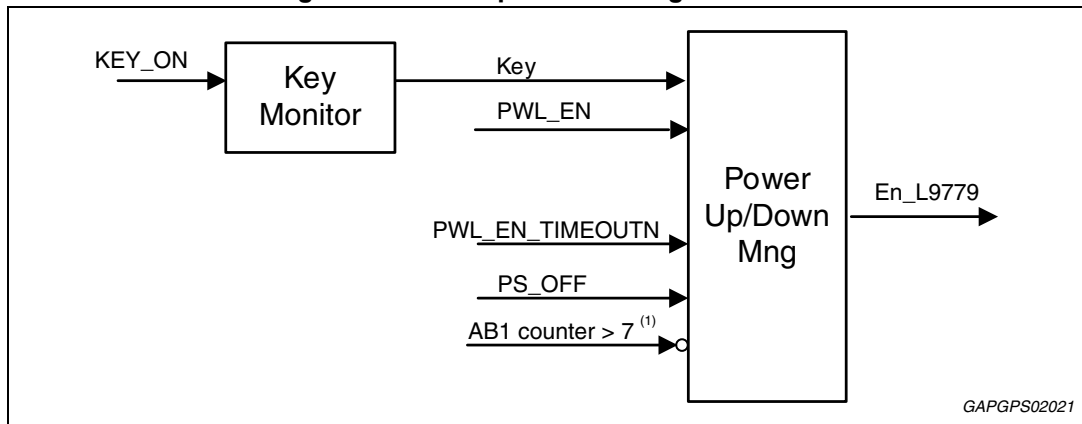
Figure 4. Configuration supplied by VB



1. The external components connected to KEY\_ON pin are mandatory in order to protect the device from ISO 7637 pulses.

## 6.2 Power-up/down management unit

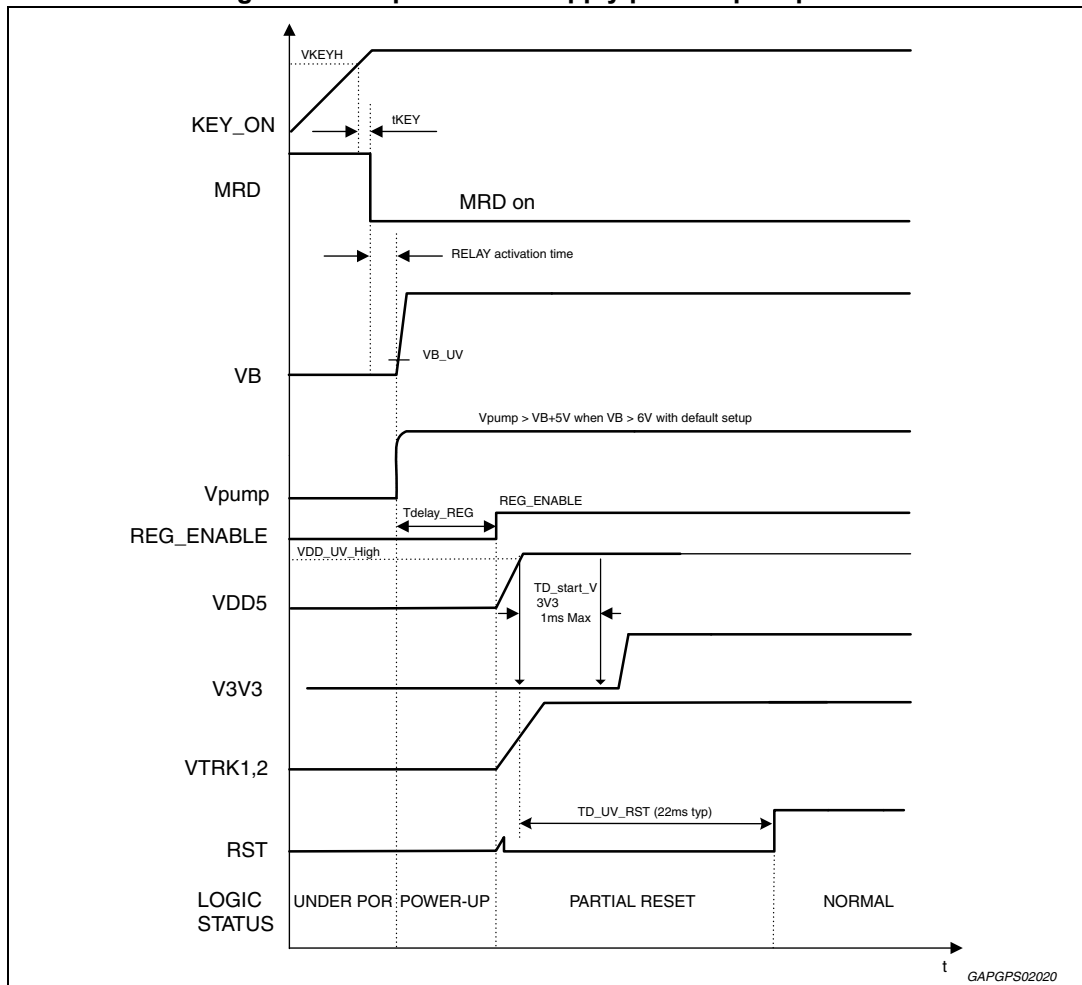
Figure 5. Power-up/down management unit



1. AB1 counter function defined at WDA Section 6.15.1.

### 6.2.1 Power-up sequence

Figure 6. Non-permanent supply power-up sequence



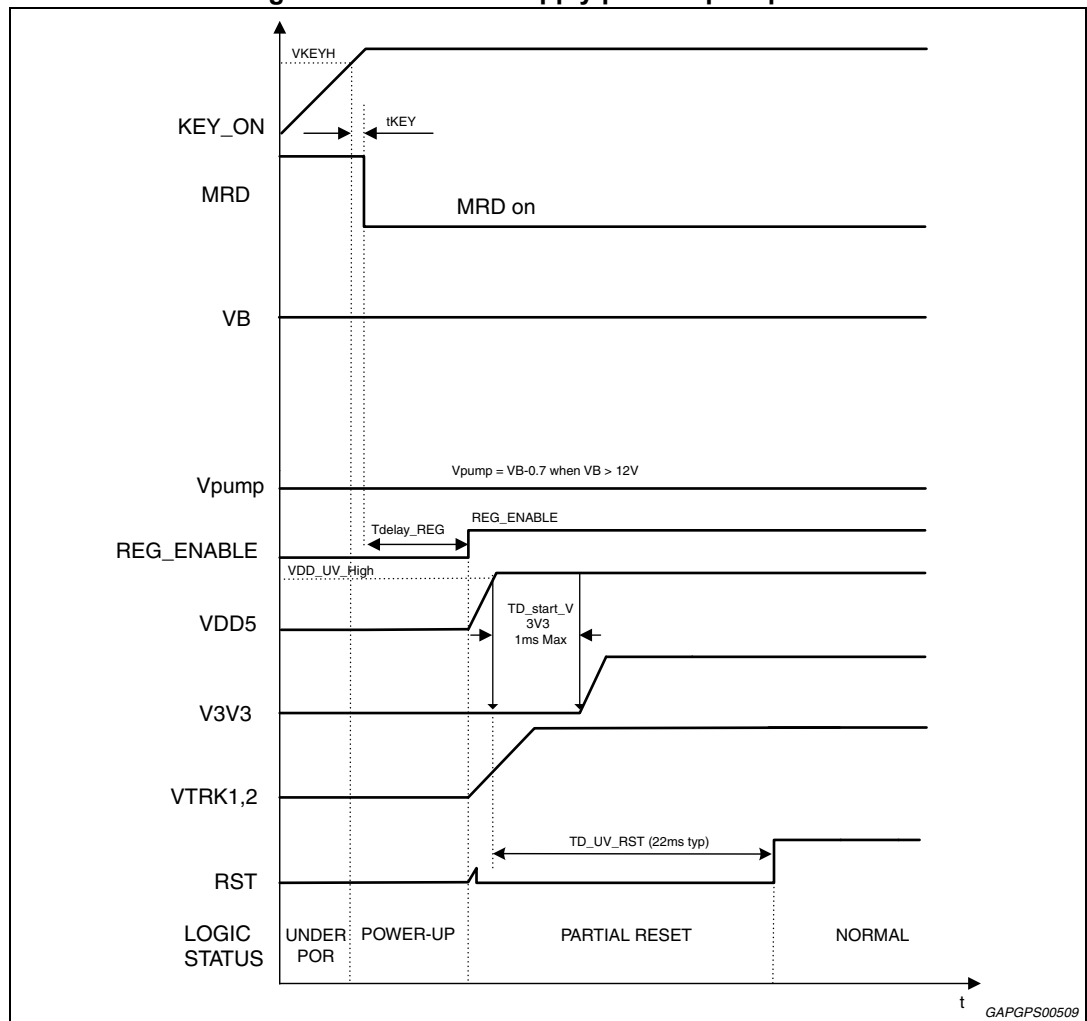
When the KEY\_ON reaches a sufficient high voltage VKEYH, after a minimum deglitch filter time T\_KEY the system is switched on. First of all the main relay driver is switched on, so the main relay connects VB pin to battery.

Control current into pin KEY\_ON is sufficient for basic functions such as filtering time, control of the main relay output stage, internal oscillator and internal bias currents.

When the voltage at VB exceeds the under voltage-detection threshold for VB (VB\_UV\_H) the internal biasing circuits are activated.

VDD5 regulator is activated Tdelay\_REG seconds later. After VDD5 exceeds the VDD\_UV threshold and with typ. 1.0 ms delay, the V3V3 is activated also. The sensor supplies VTRK1, 2 are turned on together with VDD5.

Figure 7. Permanent supply power-up sequence



In the case when VB is always connected, when the KEY\_ON voltage exceeds VKEYH the internal biasing circuits are activated.

VDD5 regulator is activated Tdelay\_REG seconds after the tKEY filter time has expired.

VDD5 regulator is activated Tdelay\_REG seconds later. After VDD5 exceeds the VDD\_UV threshold and with typ. 1.0 ms delay, the V3V3 has activated also. The sensor supplies VTRK1, 2 are turned on together with VDD5.

## 6.2.2 Power-down sequence

The system is switched off according to the status of KEY\_ON, VB and power latch mode bit PWL\_EN\_N set by the  $\mu$ C, according to:

$$\text{En\_L9779} = [(\text{!PWL\_EN\_N AND PWL\_EN\_TIMEOUTN}) \text{ OR KEY\_ON}] \text{ AND VB\_UVN}.$$

The KEY\_ON is the status of KEY\_ON pin after deglitch filter time.

En\_L9779 represents the enable signals used by different blocks.

The system will be switched off after a minimum deglitch filter time if the voltage at pin KEY\_ON is below VKEYL and if power latch mode is not active i.e. PWL\_EN\_N=1.

Otherwise, if the power latch mode is active PWL\_EN\_N=0, nothing happens until the power latch mode has finished by the  $\mu$ C writing PWL\_EN\_N=1.

However L9779WD-SPI will wait for a maximum time-out time PWL\_TIMEOUT for PWL\_EN\_N de-assertion after which the system will be forced to switch off.

PWL\_TIMEOUT can be enabled and configured by 3 bit PWL\_TIMEOUT\_CONF.

For TNL description see Smart reset circuit description.

The status of KEY\_ON can be read through the bit KEY\_ON\_STATUS. After tKEY filter time the status of KEY\_ON can be read through the bit KEY\_ON\_FLT also.

All the supply outputs shall be switched-off simultaneously. If the supplied devices have particular sequencing requirements, external diodes or clamping devices will be used.

During power down, whether the regulators are switched off at the same time as the main relay output or not is decided via the <PSOFF> bit.

- <PSOFF>='0' (default): simultaneous switching-off the regulators with the main-relay driver MRD
- <PSOFF>='1': regulators remain active when the main relay driver MRD will be switched off

With this function it is possible to detect a stuck main relay. If conditions to switch off are satisfied when <PSOFF>='1', the MRD is switched off while the voltage regulators continue to operate as long as no under voltage is detected at VB. The RST pin is not asserted till VDD\_UV. The  $\mu$ C measures the time passed since shutdown. If a certain time is exceeded, then a stuck main relay is detected and this fault is stored in the  $\mu$ C (not in the L9779WD-SPI). After this the  $\mu$ C turns off the voltage regulators by setting the bit <PSOFF> to '0' (reset state). With a stuck main relay the voltage at pin VB remains present at battery level with a current consumption of  $I_{Leak}$ .

Secure Engine Off function is that the engine can be directly switched off by the key-switch via a hardware path and without the help or interference of software or  $\mu$ C.

Whenever the KEY\_ON signal goes low the output stages mentioned in the following pages are disabled, no matter what other conditions (like e.g. "power-latch") are.

In no power latch/no SEO mode the key-switch has direct shut-off access to the injector stages (OUT1-4) and to the starter relay drivers (OUT13 and OUT14).

An additional feature for the starter delay drivers is that the starters are only shut-off after the time delay THOLD if the SEO condition is still active.

The ignition stages are not affected by the SEO signal. This is different from the WDA signal which additionally switches off the ignition stages.

To avoid misunderstandings one must be aware that the SEO function has nothing to do with the WDA function and is not a part of the WDA module. The SEO function is related to the key switch, not to the WDA function. The SEO function adds an additional safety procedure for switching off.

Other functions than the injector stages and the starter relay drivers are not affected or influenced by the SEO signal.

With the falling edge of KEY\_ON a timer is started which disables the mentioned power stages after 200 ms to 250 ms (typ. 225 ms). The timer is clocked by an internal oscillator. The timer does not depend on any  $\mu\text{C}$  clock or function. The  $\mu\text{C}$  still has control on switching on/off drivers during SEO time. This function is configured by CONFIG\_REG6 register.

**Figure 8. Power-down sequence without power latch mode**

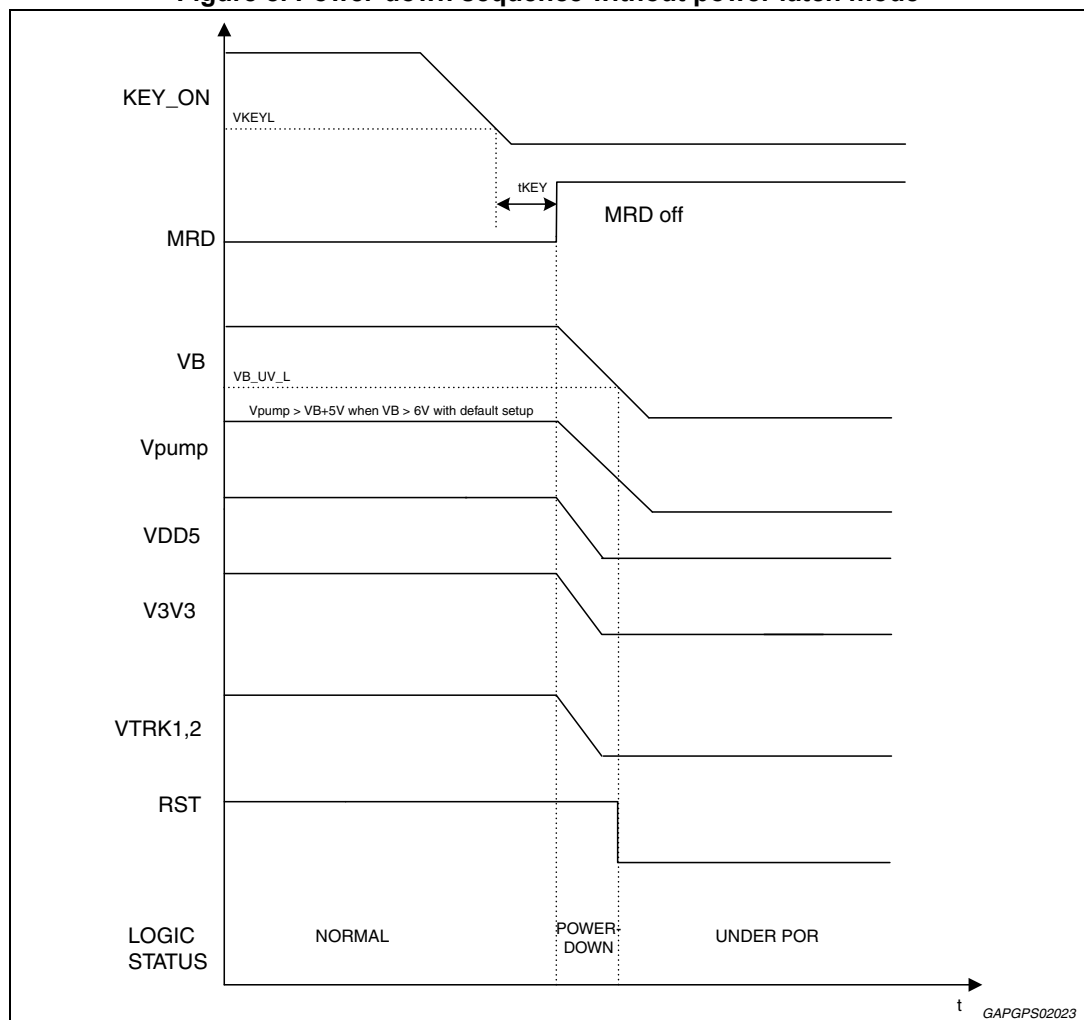




Figure 9. Power-down sequence without power latch mode and PSOFF = 1

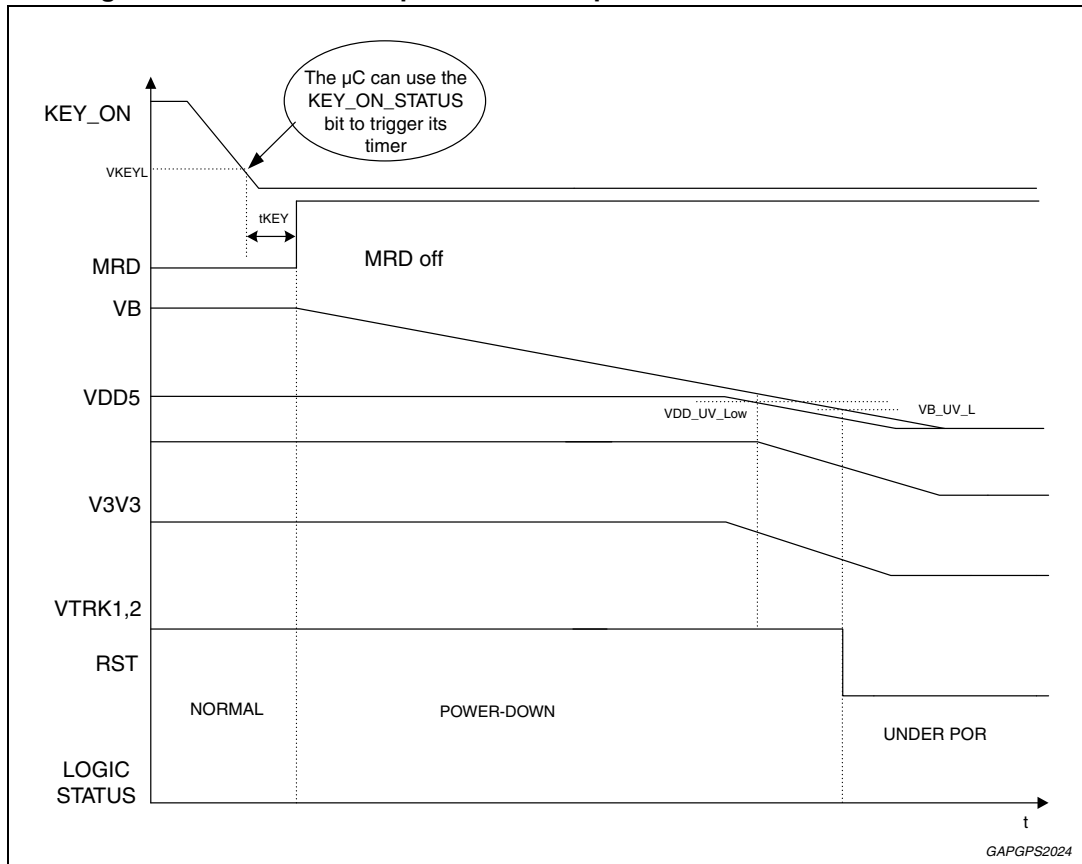


Figure 10. Power-down sequence with power latch mode

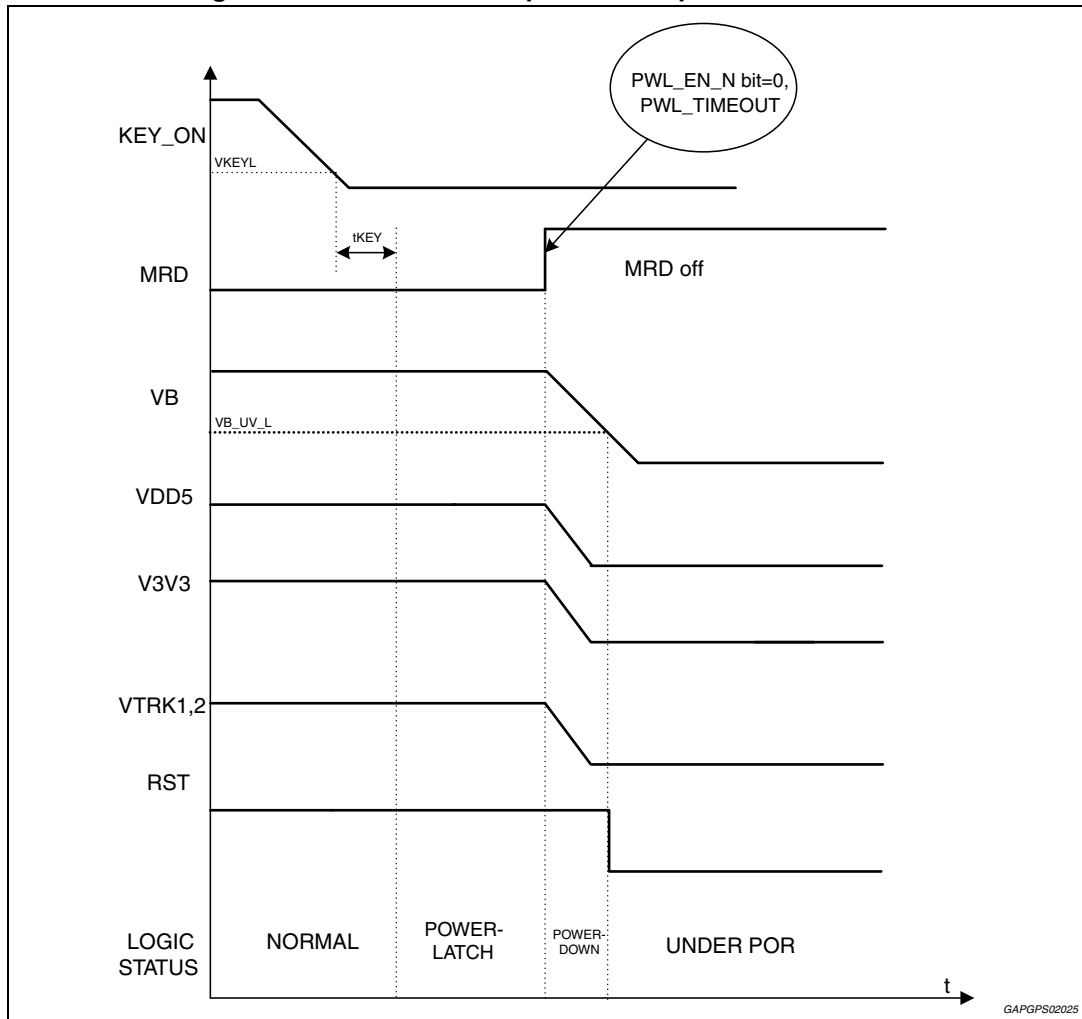


Figure 11. Power-down sequence with power latch mode and KEY\_ON toggle

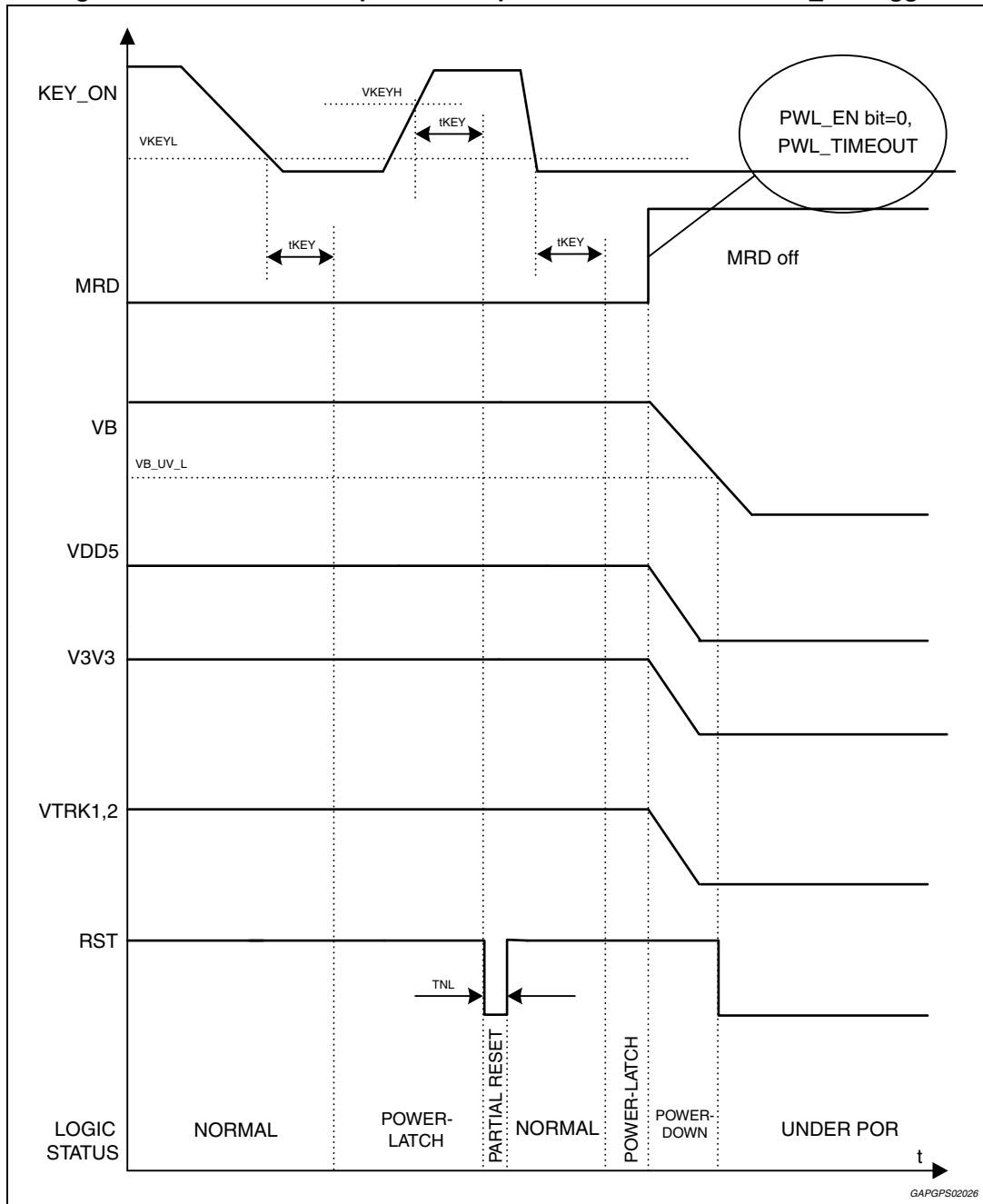
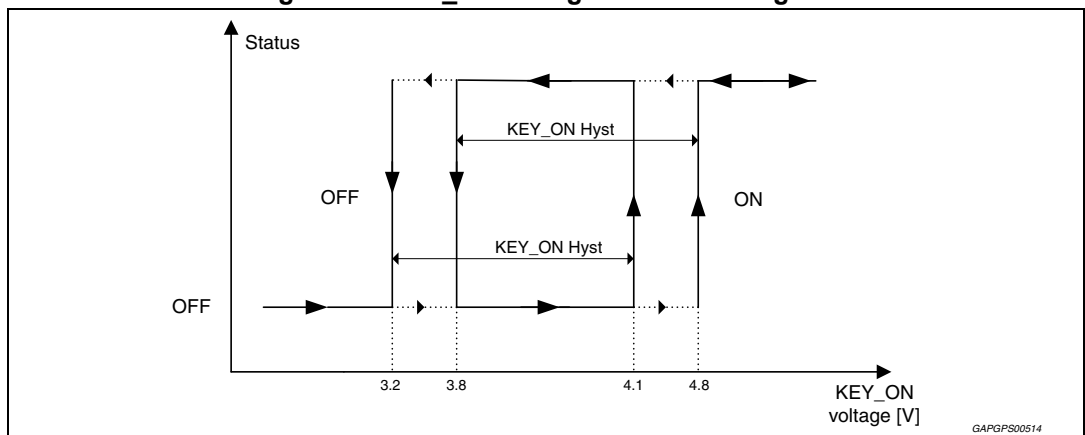


Table 7. KEY\_ON pin electrical characteristics

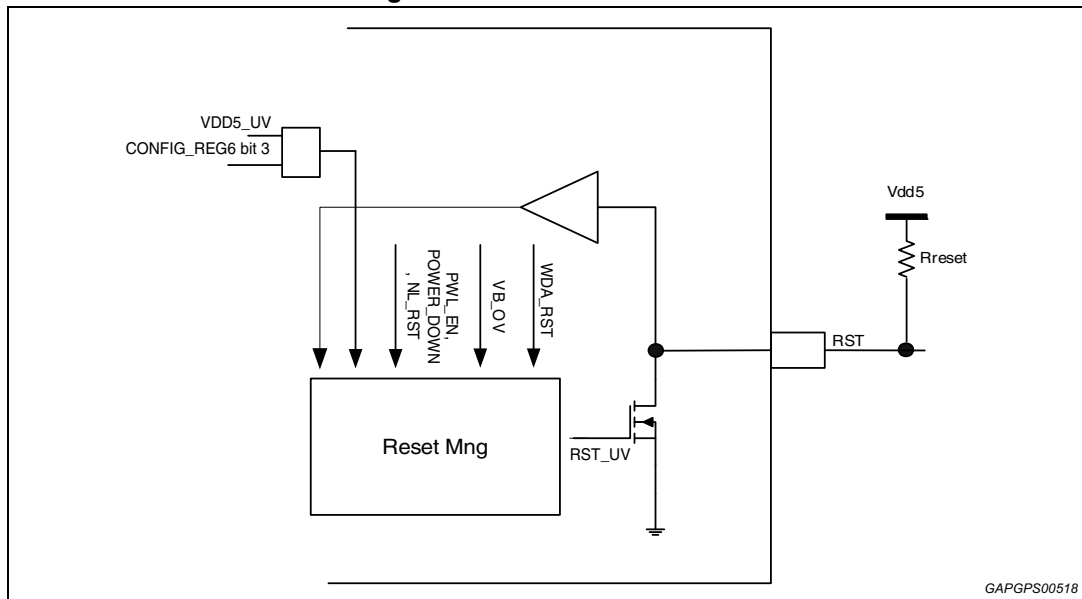
| Pin    | Symbol           | Parameter  | Test condition                 | Min  | Typ | Max | Unit |
|--------|------------------|--|--------------------------------|------|-----|-----|------|
| KEY_ON | VKEYL            | Input threshold low voltage                                    | VB = 0 to 19 V                 | 3.2  | 3.5 | 3.8 | V    |
|        | VKEYH            | Input threshold high voltage                                   |                                | 4.15 | 4.5 | 4.8 | V    |
|        | VKEYHYS          | Input voltage hysteresis                                       |                                | 0.5  | 1   | 1.5 | V    |
|        | I_KEY            | Input current  | VB = 0 to 19 V<br>KEY_ON = 5 V | -    | -   | 550 | μA   |
|        | t <sub>KEY</sub> | Filter time for switching on/off                               | VB = 0 to 19 V                 | 7.5  | 16  | 24  | ms   |
|        | Rpd              | Internal pull down resistor - NOT tested - Guarantee by design | KEY_ON = 5 V                   | 150  | -   | 400 | kΩ   |

Figure 12. KEY\_ON voltage vs. status diagram



## 6.3 Smart reset circuit

Figure 13. Smart reset circuit



### 6.3.1 Smart reset circuit functionality description

The RST pin is an input/output active when low. As output pin the Smart Reset circuit takes into account several events of the device in order to generate the proper reset signal at RST pin for the microcontroller and for a portion of the internal logic as well. As input pin RST when driven low by external source for more than  $Trst\_ft$ , it is used to reset the same portion of logic of the device.

The sources of reset are:

- VDD5 under voltage it can be disabled by SPI CONFIG\_REG6 bit3 = high, default is low i.e. enabled
- Power down
- Power latch, KEY\_ON
- VB overvoltage
- WDA\_RST, query and answer watchdog reset

Smart reset circuit generates RST signal monitoring the VDD5 according to the graph shown below: when VDD5 falls below VDD\_UV\_LOW threshold for a time longer than  $TfUV\_reset$  Smart Reset circuit asserts a RST signal (driven low) and the flag CRK\_RST is latched and resets every Read Diag operation. When VDD5 recovers to a voltage greater than VDD\_UV\_HIGH RST pin is deasserted after  $Td\_UV\_rst$ . The RST pin is also asserted at the first power-on phase when the KEY\_ON pin goes from low to high, as a consequence of the VDD5 absence.

Smart reset circuit generates an RST signal at power down independently of filtering time and VDD5 voltage level. During power latch mode if NL\_RST bit is set and KEY\_ON signal goes low to high again (before microcontroller was able to write  $PWL\_EN\_N=0$ ), RST\_PIN is asserted for time TNL.

Smart reset circuit monitors VB over voltage and generates RST signal if the over voltage lasts more than tVBOV2. When over voltage lasts more than tVBOV1 and less than tVBOV2, RST is not asserted, but all drivers are switched off without losing any configuration. In both cases the flag VB\_OV is latched and resets every Read Diag operation.

When RST is asserted to reset the  $\mu$ C, also all logic will be reset except logic involved in reset management, power up management, and power down management units. As a consequence all flags are cleared except those set by the smart reset unit, all drivers are disabled except the low battery drivers, all configuration registers are cleared and OUT\_DIS bit goes to 1. A more detailed description of the module under reset can be found in the next table. The table summaries also relations with other conditions that switch off drivers and regulator.

**Table 8. Internal reset**

| Event                           | RST pin driven low | Logic under reset  | Logic not reset   | Power-up/down manager output                     | Information FLAG |
|---------------------------------|--------------------|--|---|--|------------------|
| Power down                      | Yes                | Internal registers<br>Interfaces drivers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS | Smart reset function<br>Power-up/down manager   | MRD=OFF<br>VDD5=OFF<br>V3V3=OFF<br>VTRACK1,2=OFF | N/A              |
| Power latch +KEY_ON rising edge | Yes For TNL        | Internal registers<br>Interfaces drivers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS | Smart reset function<br>Power-up/down manager   | MRD=ON<br>VDD5=ON<br>V3V3=ON<br>VTRACK1,2=ON     | TNL_RST          |
| VDD5 under voltage $t < THOLD$  | Yes                | Internal registers<br>Interfaces drivers<br>CAN & K-LINE & VRS   | LB interfaces drivers<br>LB internal registers<br><br>Smart reset function<br>Power-up/down manager   | MRD=ON<br>VDD5=ON<br>V3V3=ON<br>VTRACK1,2=ON     | CRK_RST          |
| VDD5 under voltage $t > THOLD$  | Yes                | Internal registers<br>Interfaces drivers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS | Smart reset function<br>Power-up/down manager   | MRD=ON<br>VDD5=ON<br>V3V3=ON<br>VTRACK1,2=ON     | VDD5UV_RST       |
| VDD5 over voltage               | No                 | Interfaces drivers   | Internal registers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS<br><br>Smart reset function<br>Power-up/down manager | MRD=ON<br>VDD5=ON<br>V3V3=ON<br>VTRACK1,2=ON     | VDD5_OV          |

Table 8. Internal reset (continued)

| Event  | RST pin driven low | Logic under reset  | Logic not reset  | Power-up/down manager output                    | Information FLAG |
|--|--------------------|--|--|---|------------------|
| VB over voltage<br>$t_{TBOV1} < t < t_{TBOV2}$ | No                 | Interfaces drivers<br>LB interfaces drivers  | Internal registers<br>LB internal registers<br>CAN & K-LINE & VRS<br><br>Smart reset function<br>Power-up/down manager | MRD=ON<br>VDD5=ON<br>V3V3=ON<br>VTRACK1,2=ON    | OV_RST           |
| VB over voltage<br>$t > t_{TBOV2}$             | Yes                | Internal registers<br>Interfaces drivers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS | Smart reset function<br>Power-up/down manager  | MRD=ON<br>VDD5=OFF<br>V3V3=OFF<br>VTRACK1,2=OFF | OV_RST           |
| RST driven low externally<br>$t < THOLD$       | Yes                | Internal registers<br>Interfaces drivers<br>CAN & K-LINE & VRS   | LB interfaces drivers<br>LB internal registers<br><br>Smart reset function<br>Power-up/down manager                    | Keep state                                      | N/A              |
| RST driven low externally<br>$t > THOLD$       | Yes                | Internal registers<br>Interfaces drivers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS | Smart reset function<br>Power-up/down manager  | Keep state                                      | N/A              |
| Software reset sent by the $\mu$ C through SPI | No                 | Internal registers<br>Interfaces drivers<br>LB interfaces drivers<br>LB internal registers<br>CAN & K-LINE & VRS | Smart reset function<br>Power-up/down manager  | MRD=ON<br>VDD5=ON<br>V3V3=ON<br>VTRACK1,2=ON    | N/A              |

**Legend:**

Internal registers = configuration registers  
 Interfaces driver = control registers (OUT\_DIS), LS/HS drivers, ext-MOS, IGBT  
 LB internal registers = include dedicated configuration bit for Low battery drivers  
 LB interfaces driver = control registers (OUT\_DIS) + interface drivers logic for Low battery drivers  
 Smart reset logic = include VDD5 undervoltage and some time counter (TNL, D\_UV\_RST, THOLD)

Power-up/down manager = include the logic for regulator control and monitoring and MRD managing.

CAN & K-LINE & VRS

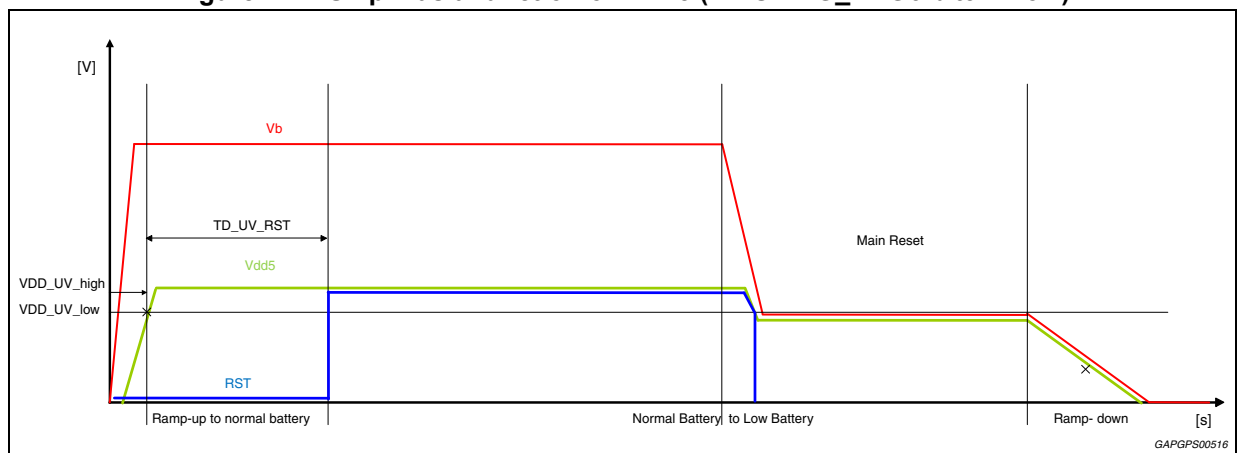
**Table 9. RST pin external components required**

| Pin | Symbol             | Parameter               | Value        | Note |
|-----|--------------------|-------------------------|--------------|------|
| RST | R <sub>reset</sub> | Pull_up reset reference | 4.7 kΩ ± 5 % | -    |

**Table 10. RST pin electrical characteristics**

| Pin              | Symbol                  | Parameter                   | Test condition                                 | Min  | Typ | Max     | Unit |
|------------------|-------------------------|-----------------------------|--|------|-----|---------|------|
| <b>As output</b> |                         |                             |  |      |     |         |      |
| RST              | VUV_LO                  | Output low voltage          | 1 < VDD5 < VDD_UV<br>R <sub>reset</sub> = 4.7K | -    | -   | 0.4     | V    |
|                  | IUVres_max              | Input current               | VDD5 = VDD_UV<br>V <sub>UV_reset</sub> = 0.6 V | 1    | -   | -       | mA   |
|                  | I <sub>lkUV_reset</sub> | Input leakage current       | V <sub>UV_reset</sub> > VDD_UV                 | -    | -   | 1       | μA   |
|                  | TD_UV_RS<br>T           | Power-on reset delay        | Tested by scan                                 | 17   | -   | 30      | ms   |
|                  | TNL                     | Power latch mode exit delay | Tested by scan                                 | 1.4  | 2   | 2.6     | ms   |
| <b>As input</b>  |                         |                             |  |      |     |         |      |
| RST              | RST_L                   | RST Input low voltage       | -  | -0.3 | -   | 1.1     | V    |
|                  | RST_H                   | RST input high voltage      | -  | 2.3  | -   | VDD+0.3 | V    |
|                  | Trstflt                 | Reset filter time           | Tested by scan                                 | 7.5  | 10  | 12.5    | μs   |
|                  | R <sub>RST_PU</sub>     | RST pull-up resistor        | -  | 50   | -   | 250     | kΩ   |

**Figure 14. RST pin as a function of VDD5 (if CONFIG\_REG6 bit3 = Low)**





## 6.4 Thermal shut down

There are 4 temperature sensors:

- OT1 for VTRK1,2
- OT2 for OUT1...10, OUT13...20, OUTA...D, IGN1...4.
- OT3 for MRD
- OT4 for V3V3

When OT1 is higher than  $\theta_{\text{junction}}$  for  $t_{\text{OT}}$  time VTRK1,2 are switched off if they are in current limitation.

When OT1 is lower than  $\theta_{\text{junction}} - \theta_{\text{HYSTERESISV}}$  for  $t_{\text{OT}}$  time, the device should return to normal operation automatically.

When OT2 is higher than  $\theta_{\text{junction}}$  for  $t_{\text{OT}}$  time all the OUTx and IGNx are switched off.

When OT2 is lower than  $\theta_{\text{junction}} - \theta_{\text{HYSTERESISV}}$  for  $t_{\text{OT}}$  time, the device should return to normal operation automatically.

When OT3 is higher than  $\theta_{\text{junction}}$  for  $t_{\text{OT}}$  time the MRD is switched off.

When OT3 is lower than  $\theta_{\text{junction}} - \theta_{\text{HYSTERESISV}}$  for  $t_{\text{OT}}$  time, the device should return to normal operation automatically.

When OT4 is higher than  $\theta_{\text{junction}}$  for  $t_{\text{OT}}$  time the V3V3 is switched off if it is in current limitation.

When OT4 is lower than  $\theta_{\text{junction}} - \theta_{\text{HYSTERESISV}}$  for  $t_{\text{OT}}$  time, the device should return to normal operation automatically.

Thermal warning information from OT1,OT2,OT3,OT4 is latched and communicated by SPI.

Thermal warning information is reset when it is read.

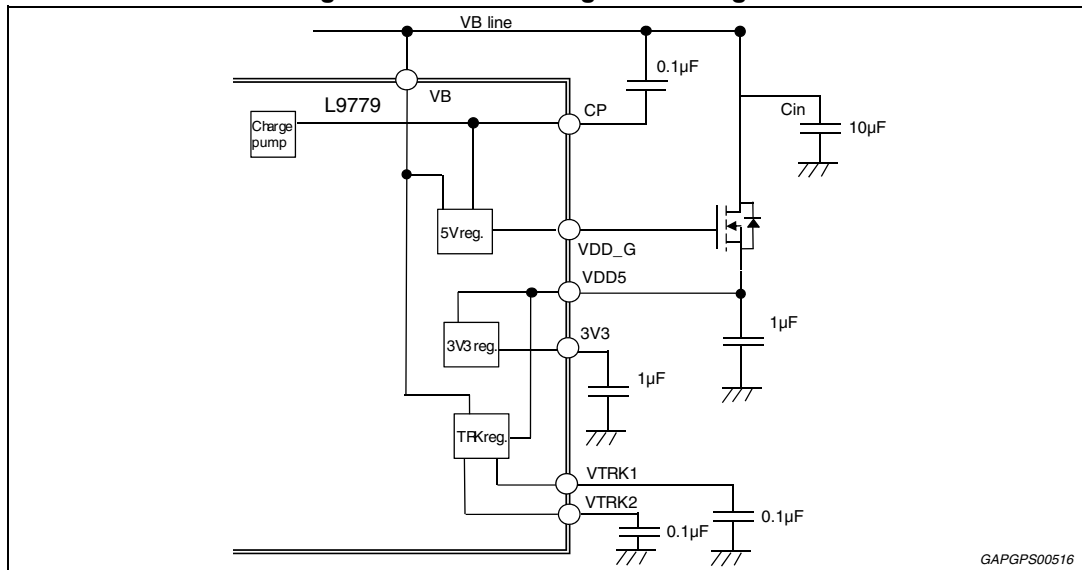
The latch behavior affects only flags bit, while drivers and supplies use the OTx just after the filter to return to normal operation.

**Table 11. Temperature information**

| Parameter                    | Value      | Unit |
|------------------------------|------------|------|
| $\theta_{\text{junction}}$   | 165 to 185 | °C   |
| $\theta_{\text{HYSTERESIS}}$ | 5-10       | °C   |
| $t_{\text{OT}}$              | 20         | µs   |

## 6.5 Voltage regulators

Figure 15. Structure regulators diagram



The structure of regulators is showed in the above figure.

The 5 V voltage is obtained through a linear regulator using an external N-Mos. The precision is  $\pm 2\%$  with  $I_{max} = 400$  mA. The high precision is obtained with a pre-trimmed reference voltage. The under-voltage condition is monitored through the Smart Reset circuit. In addition there is an overvoltage monitor that after  $t_{VDD5\_OV}$  time switches off the drivers except the MRD, OUT13, OUT14, OUT21, OUT25. To switch on again the output it is necessary to send again the START command and to write the CONTROL registers.

It is present a VDD5 over voltage flag, VDD5\_OV, that is latched and cleared after reading. This flag does not inhibit the drivers switch on.

The 3.3 V voltage is obtained through a linear regulator. The precision is  $\pm 2\%$  with  $I_{max} = 100$  mA.

Over-current protection is provided and operates together with thermal sensor OT4.

The condition that switches off the V3V3 is the logic of both Thermal Warning and Over Current.

The under-voltage condition is monitored and the non latched information is available V3V3\_UV bit.

VTRK1, 2 are two voltage regulators in tracking ( $\pm 20$  mV) with the VDD5 voltage for Sensors Supply. They can supply sensors with a  $I_{max} = 100$  mA. The output voltages can be used in parallel.

VTRK supplies are protected from over voltage due to short to VB with back to back protection and non latched information are available on VTRK1\_DIAG and VTRK22\_DIAG bits.

Over-current protection is provided as well and operates together with thermal sensor OT1.

The condition that switches off the VTRK 1, 2 is the logic of thermal warning and over current.

The non latched information is available for overload and over temperature conditions in VTRACK\_DIAG bit.

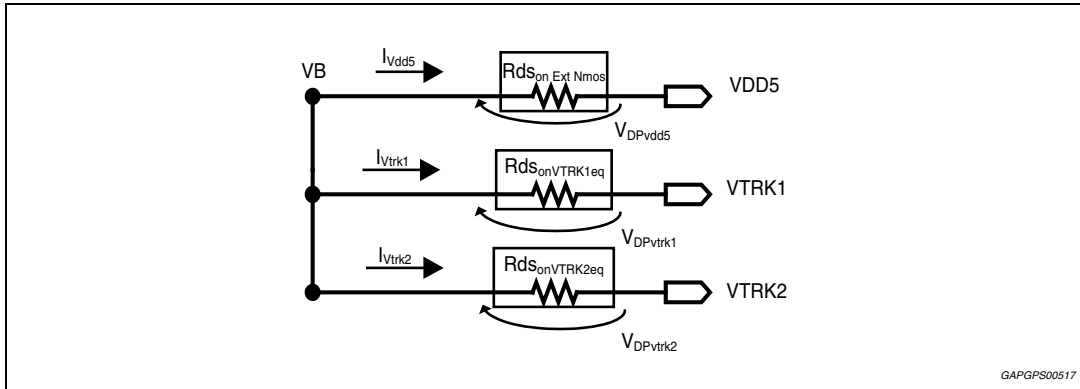
If the VB voltage is lower than regulated VDD5 and higher than 4.15 V the value of VDD5 and VTRK1, 2, could be calculated by the following method:

$$V_{DPVDD5} = (R_{ds_{on\ ExtNmos}}) \cdot (I_{VDD5} + I_{V3V3})$$

$$V_{DPvtrk1} = (R_{ds_{onVTRK1}}) \cdot I_{VTRK1}$$

$$V_{DPvtrk2} = (R_{ds_{onVTRK2}}) \cdot I_{VTRK2}$$

Figure 16. Graphic representation of the calculation method



$$VDD5 = VB - (V_{DPVdd5})$$

$$VTRK\ 1, 2 = VB - (V_{DPVtrk1,2})$$

While V3V3 keeps working as expected till VB = 4.15 V

Table 12. Voltage regulators external components required

| Pin   | Symbol             | Parameter                | Min    | Typ | Max   | Suggested part number   |
|-------|--------------------|--------------------------|--------|-----|-------|---|
| VTRK1 | C <sub>TRK1</sub>  | External VTRK1 capacitor | 100 nF | -   | 1 μF  | C1005X7R1C104K--0.1μF<br>C1608X7R1H104K--0.1μF  |
| VTRK2 | C <sub>VTRK2</sub> | External VTRK2 capacitor | 100 nF | -   | 1 μF  |   |
| VDD5  | C <sub>VDD5</sub>  | External VDD5 capacitor  | 1 μF   | -   | 10 μF | C2012X7R1E105K--1μF<br>C1608X7R1C105K-- μF<br>C3216X7R1H105K--1μF<br>C3225X7R1E106K--10μF<br>C3225X7R1C106K--10μF |
|       | Ext MOS            | External N-MOS           | -      | -   | -     | IRFZ24NSTRL; STD20NF06L (testing reference);<br>NTD18N06L;<br>HUF76419D3  |

Table 12. Voltage regulators external components required (continued)

| Pin  | Symbol            | Parameter                      | Min  | Typ   | Max   | Suggested part number   |
|------|-------------------|--------------------------------|------|-------|-------|---|
| V3V3 | C <sub>V3V3</sub> | External V3V3 capacitor        | 1 μF | -     | 10 μF | C2012X7R1E105K--1μF<br>C1608X7R1C105K--1μF<br>C3216X7R1H105K--1μF<br>C3225X7R1E106K--10μF<br>C3225X7R1C106K--10μF |
| CP   | CP                | External charge pump capacitor | -20% | 100nF | +20%  | -   |

Capacitor legend:

1H → 50 V

1E → 25 V

1C → 16 V

X7R → -40 to 125 °C ±15%

K → -40 to 125 °C ±10%

Note: Others N-MOSFET can be used provided that they have similar threshold voltage and input capacitance; however regulator transient performances may have deviation to be checked.

PCB layout Note: The C<sub>in</sub> capacitor on VB line should be put as close as possible to the drain of external MOS. The suggestion PCB layout is as below.

Figure 17. Circuit and PCB layout suggested

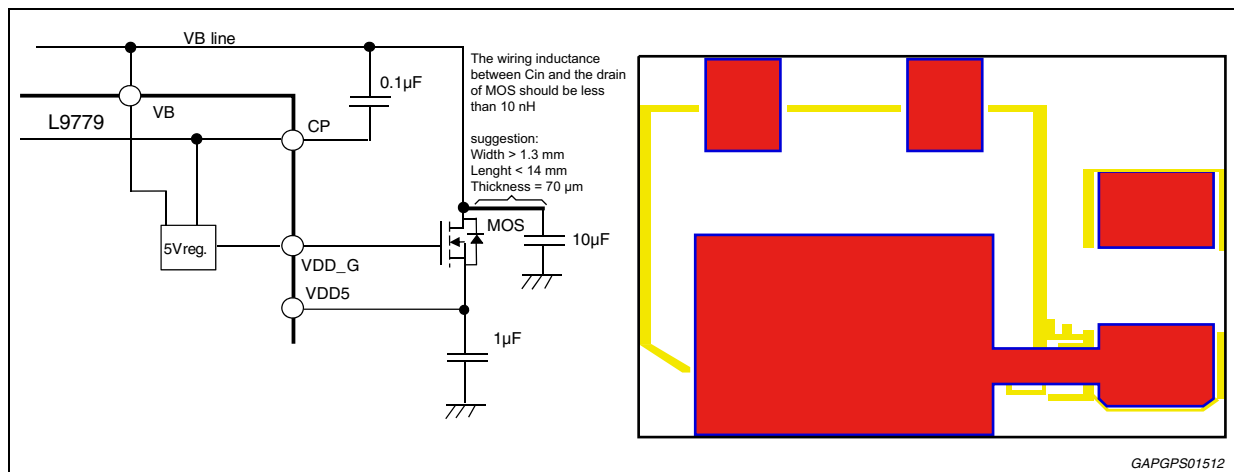


Table 13. VB Power supply electrical characteristics

| Pin         | Symbol                              | Parameter                              | Test Condition   | Min  | Typ | Max   | Unit    |
|-------------|-------------------------------------|--|--|------|-----|-------|---------|
| VB          | $I_b$                               | Quiescent current from VB pin          | VB = 16 V<br>Min. load on regulator outputs <sup>(1)</sup> | -    | -   | 50    | mA      |
|             | $I_{Leak}$                          | Standby current                        | VB = 16V; VKEY_ON = GND<br>Guaranteed at room temp.        | -    | -   | 10    | $\mu$ A |
|             |                                     |  | VB = 16V; VKEY_ON = GND<br>Guaranteed at hot temp.         | -    | -   | 100   |         |
|             | VB_UV_H                             | Under voltage switch on threshold high | MRD, Low battery channels switch-on in power up            | -    | -   | 4.8   | V       |
|             | VB_UV_L                             | Under voltage switch off threshold Low | MRD, Low battery channels switch-off                       | 3.5  | -   | 4.145 |         |
|             | VB_OV_UP                            | Over voltage switch off threshold      | -  | -    | -   | 32    | V       |
|             | VB_OVh                              | Over voltage threshold hysteresis      | -  | 0.3  | -   | 1     | V       |
|             | VB_OV_DO<br>WN                      | Over voltage switch off threshold      | -  | 28.5 | -   | -     | V       |
|             | $t_{VBOV1}$                         | Filter time for drivers turn-off       | Tested by scan   | 63   | 85  | 107   | $\mu$ s |
| $t_{VBOV2}$ | Filter time for regulators turn-off | Tested by scan                         | 11   | 15   | 19  | ms    |         |

1. Min. load on regulator output is  $V_{trk1} = 1$  mA,  $V_{trk2} = 1$  mA,  $V_{3V3} = 5$  mA, VDD5 is open. (5 mA on V3V3 is from VDD5)

Figure 18. VB overvoltage diagram

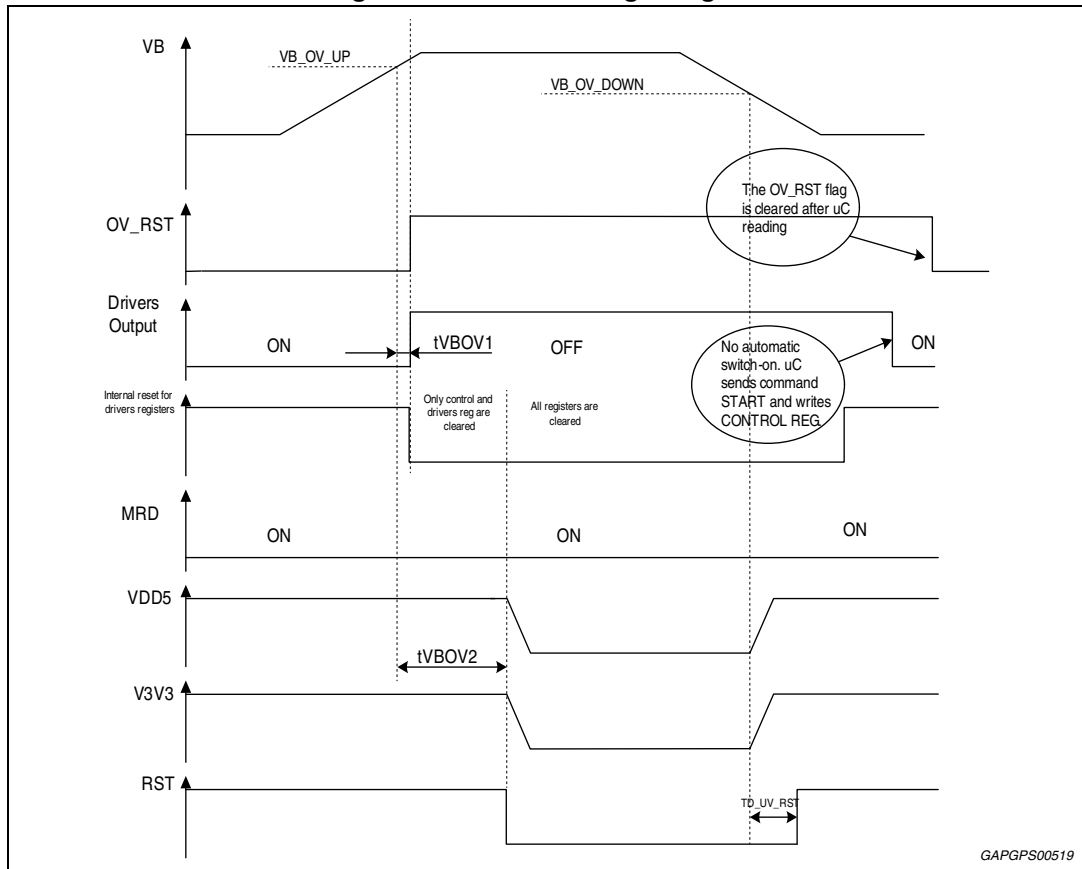


Table 14. Linear 5 V regulator electrical characteristics

| Pin  | Symbol              | Parameter                            | Test condition  | Min         | Typ    | Max         | Unit |
|------|---------------------|--------------------------------------|---|-------------|--------|-------------|------|
| VDD5 | VDD5                | Output voltage 5 V                   | $I_{VDD5} = 5$ to 400 mA<br>$V_{bat} = 6-18$ V  | 4.9         | 5      | 5.1         | V    |
|      | VDD5                | Transient load regulation            | Square wave on VDD5,<br>$\Delta I_{DD5} = \pm 100$ mA; $F_0 = 5$ kHz;<br>$t_r = t_f = 0.5$ $\mu$ s; within the<br>output current range<br>NO reset occurs.<br>$C_{out} = 1$ $\mu$ F<br>$C_{out} = 10$ $\mu$ F | 4.8<br>4.85 | 5<br>5 | 5.2<br>5.15 | V    |
|      | $S_{r_{power-up5}}$ | Output voltage slew rate at power-up | $I_{vdd5} = 50$ mA; $C_{out} = 10$ $\mu$ F  | 5           | 15     | 25          | V/ms |
|      | $V_{line\_5}$       | Line regulation voltage              | $I_{VDD5} = 5$ to 400 mA<br>$6$ V < $V_b$ < 18 V  | -           | -      | 25          | mV   |
|      | $V_{load\_5}$       | Load regulation voltage              |   | -           | -      | 25          | mV   |
|      | $VDD5_{Drift}$      | Total output VDD5 voltage drift      | $C_{out} = 1$ $\mu$ F (parameter validated in reliability test)   | -           | -      | 100         | mV   |

Table 14. Linear 5 V regulator electrical characteristics (continued)

| Pin   | Symbol              | Parameter                            | Test condition   | Min               | Typ      | Max                   | Unit |
|-------|---------------------|--------------------------------------|--|-------------------|----------|-----------------------|------|
| VDD5  | SVR <sub>VDD5</sub> | Supply voltage 5 V rejection         | C <sub>out</sub> = 10 µF; 4 V <sub>pp</sub> , VB mean 9 V, f = 20 kHz  | 40                | -        | -                     | dB   |
|       | VDD_OS              | Max overshoot at switch on           | V <sub>bat</sub> = 18 V C <sub>out</sub> = 1 µF<br>R <sub>out</sub> = 100 Ohm  | -                 | -        | 5.2                   | V    |
|       |                     | Max overshoot exiting from cranking  | Not tested, is guaranteed by design.   | -                 | -        | 5.2                   | V    |
|       | Tdelay_REG          | -                                    | Tested by scan <sup>(1)</sup>  | 0.75              | 1        | 1.25                  | ms   |
|       | VDD_UV_low          | VDD5 undervoltage low threshold      | -  | 4.5               | -        | VDD5 (typ.)<br>-150mV | V    |
|       | VDD_UV_hys          | VDD5 undervoltage hysteresis         | -  | 50                | -        | -                     | mV   |
|       | VDD_UV_high         | VDD5 undervoltage high threshold     | -  | 4.5               | -        | VDD5 (typ.)<br>-40 mV | V    |
|       | VDD_OV_high         | VDD5 overvoltage high threshold      | -  | 5.8               | -        | 6.2                   | V    |
|       | VDD_OV_hys          | VDD5 overvoltage hysteresis          | -  | 310               | -        | 460                   | mV   |
|       | VDD_OV_low          | VDD5 overvoltage low threshold       | -  | 5.5               | -        | 5.9                   | V    |
|       | t_VDD5_OV           | VDD5 overvoltage filter time         | Tested by scan <sup>(1)</sup>  | -                 | 100      | -                     | µs   |
|       | TfUV_Reset          | VDD5 under voltage reset filter      | Tested by scan <sup>(1)</sup>  | 25                | 50       | 75                    | µs   |
| VDD_G | VDD_G               | External device voltage at pin VDD_G | VB = 4.5 V   | 9.5               | -        | -                     | V    |
|       | Vgs_clamp           | External N-DMOS Vgs clamp            | Iclamp = 20 mA   | -                 | VDD5 +10 | -                     | V    |
|       | Ig                  | Driver capability                    | VB = 6-18 V<br>Open loop,<br>VDD5 = VDD_G = 0 V  | 500               | -        | -                     | µA   |
|       | Ig_rdson            | Driver capability                    | VB = 4.5 V = VDD_G, open loop, VDD5 = 0 V<br>(charge pump current capability to keep ext MOS in Rdson mode during crank) | 160               | -        | -                     | µA   |
| -     | Fcp                 | Oscillator frequency                 | VB = 6-18 V  | Fcp (typ.)<br>-5% | 9.984    | Fcp (typ.)<br>+5%     | MHz  |

1. All tests by scan parameters have 25% tolerance.

## 6.6 Charge pump

The L9779WD-SPI charge pump could be active if the battery supply voltage is smaller than 12 V or be permanently active by setting the capful bit enable or disable. Charge pump provides a permanent voltage of at least 5 V above  $U_{bat}$  when  $U_{bat}$  is higher than 6 V with an external load current at pin CP of 50  $\mu A$  additional to the L9779WD-SPI internal loads.

Once  $U_{bat}$  overvoltage is detected ( $V_{B\_OV\_th} > 28 V$ ), the charge pump will be switched off automatically no matter the  $cp\_off$  bit status.

Figure 19. VDD5 overvoltage diagram

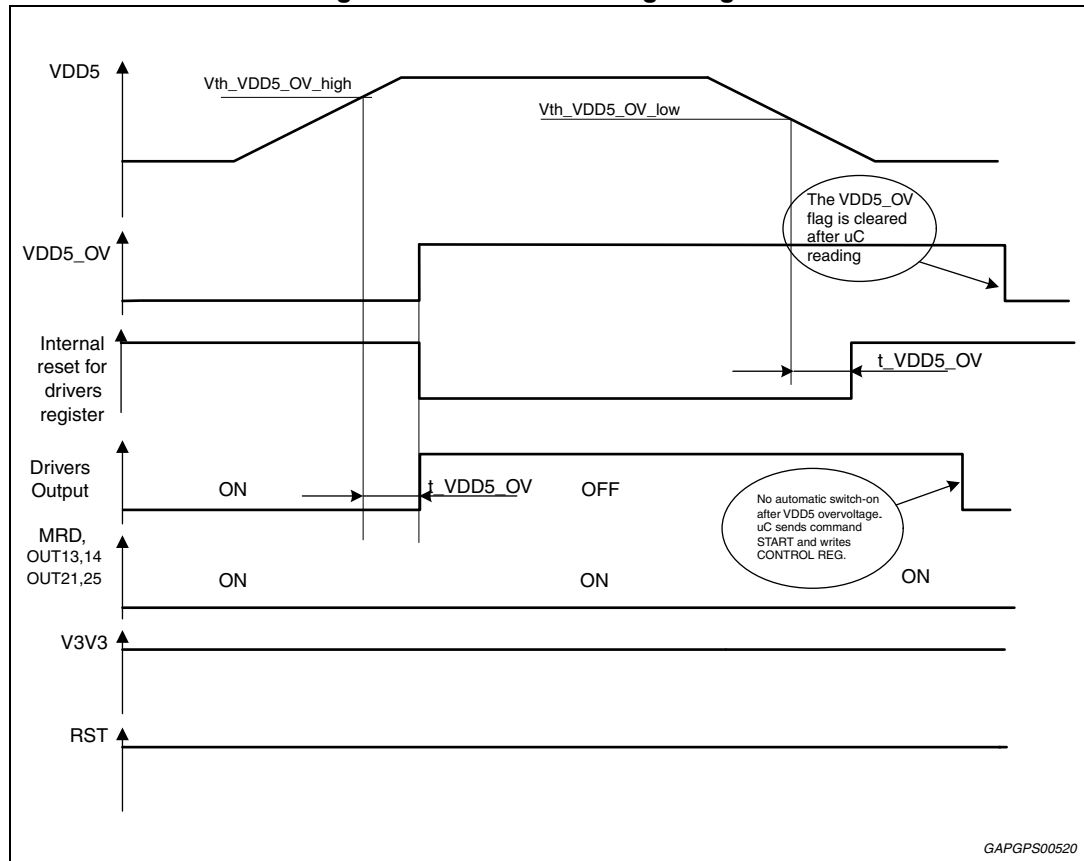




Figure 20. VDD5 vs battery: ramp-up diagram

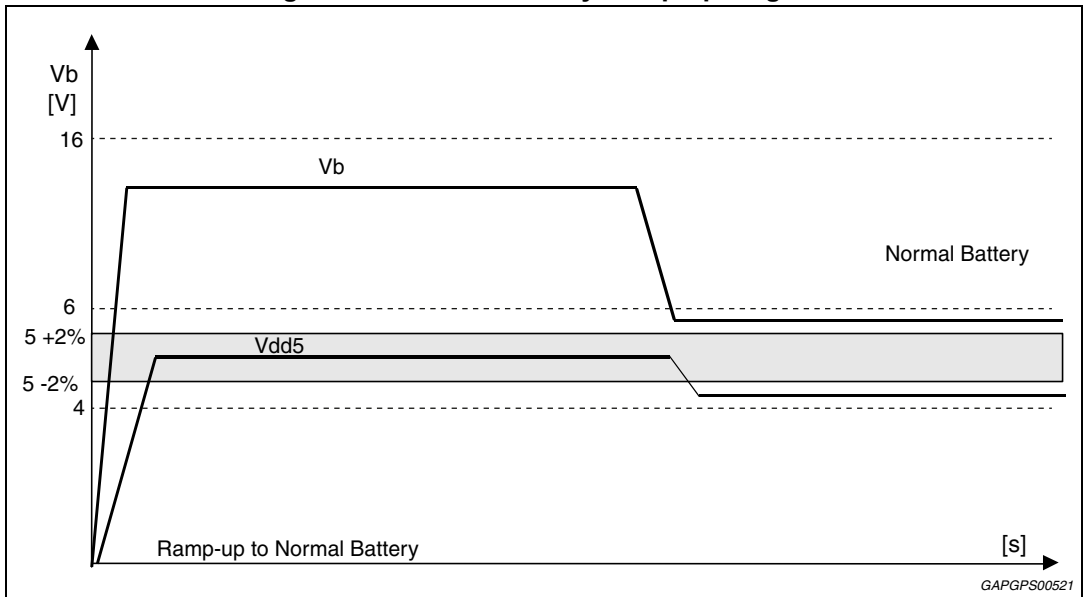
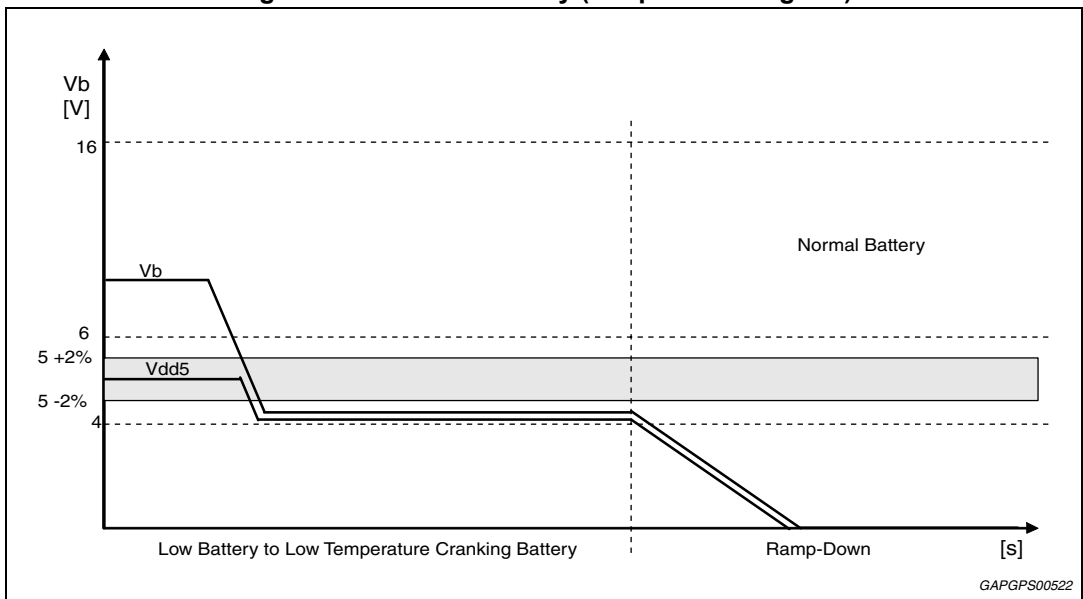


Figure 21. VDD5 vs battery (ramp-down diagram)



**Table 15. Linear 3.3 V regulator electrical characteristics**

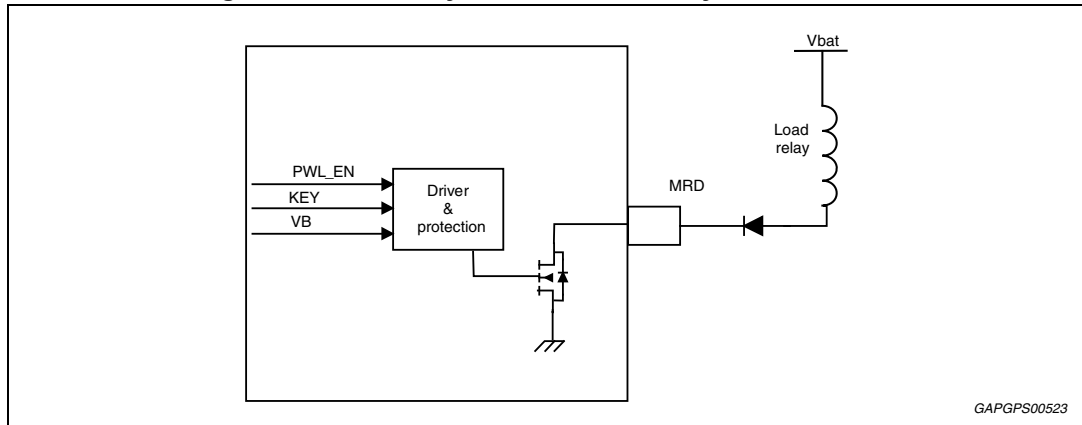
| Pin  | Symbol                     | Parameter   | Test condition  | Min  | Typ | Max  | Unit |
|------|----------------------------|---|---|------|-----|------|------|
| V3V3 | V3V3                       | Output voltage 3.3 V                                | IV3V3 = 5-100 mA<br>VB = 6-18 V   | 3.23 | 3.3 | 3.36 | V    |
|      | V3V3                       | Output voltage 3.3 V                                | Square wave on V3V3, $\Delta IV3V3 = \pm 20$ mA; $f_0 = 5$ kHz; $t_r = t_f = 0.5 \mu s$ ; within the output current range | 3.2  | 3.3 | 3.36 | V    |
|      | Sr <sub>power-up5</sub>    | Output voltage slew rate at power-up                | I <sub>V3V3</sub> = 12.5 mA<br>C <sub>out</sub> = 4.7 $\mu F$   | 4    | 12  | 20   | V/ms |
| V3V3 | I <sub>V3V3_MAX</sub>      | Output current limitation V3V3                      | V3V3 = 3 V<br>VB = 6-18 V   | 200  | -   | 500  | mA   |
|      | V <sub>line_3</sub>        | Line regulation voltage                             | IV3V3 = 5-100 mA<br>6V < VB < 18 V  | -    | -   | 25   | mV   |
|      | V <sub>load_3</sub>        | Load regulation voltage                             | IV3V3 = 5-100 mA<br>6V < VB < 18 V  | -    | -   | 25   | mV   |
|      | V3V3 <sub>Drift</sub>      | Total output 3V3 voltage drift                      | C <sub>out</sub> = 4.7 $\mu F$ (parameter validated by reliability test)  | -    | -   | 100  | mV   |
|      | SVRV <sub>3V3</sub>        | Supply voltage 3.3 V rejection                      | C <sub>out</sub> = 4.7 $\mu F$ ;<br>4 V <sub>pp</sub> , VB mean 9 V, f = 20 kHz   | 40   | -   | -    | dB   |
|      | V <sub>drop_out</sub>      | -   | VDD5 = 3.3 V; IV3V3 = 100 mA  | -    | -   | 200  | mV   |
|      | V3V3_OS                    | Max overshoot at switch on                          | -   | -    | -   | 3.45 | V    |
|      | -                          | Max overshoot exiting from cranking*1               | Not tested, it is guaranteed by design  | -    | -   | 3.45 | V    |
|      | TD_Start_V3V3 <sub>3</sub> | Delay between VDD5 > VDD_UV_high and V3V3 switch on | Tested by scan  | -    | -   | 1    | ms   |

Table 16. 5V tracking sensor supply electrical characteristics

| Pin                    | Symbol   | Parameter                            | Test condition  | Min         | Typ | Max                   | Unit       |
|------------------------|--|--------------------------------------|---|-------------|-----|-----------------------|------------|
| VTRK_1<br>VTRK_2       | $\Delta$ VTRK                                    | Output voltage tracking error        | VB = 6-18 V<br>1 mA < IVTRK < 100 mA  | VDD5<br>-20 | -   | VDD5<br>+20           | mV         |
|                        | I <sub>VTRK_MAX</sub>                            | Output current limitation<br>VTRK1,2 | VTRK = -1V  | 160         | -   | 400                   | mA         |
|                        | V <sub>LINE_trk</sub>                            | Line regulation voltage VTRK         | VB = 6-18 V<br>1 mA < IVTRK < 100 mA<br>Ctrk = 1 $\mu$ F                        | -           | -   | 20                    | mV         |
|                        | V <sub>load_trk</sub>                            | Load regulation voltage VTRK         | VB = 6-18 V<br>1 mA < IVTRK < 100 mA<br>Ctrk = 1 $\mu$ F                        | -           | -   | 20                    | mV         |
|                        | I <sub>sink_VTRK</sub>                           | Short circuit reverse current        | Output shorted<br>to Vbat +2 V  | -           | -   | 4                     | mA         |
|                        | I <sub>TH_UVTRK</sub>                            | Over current threshold VTRK          | VB = 6-18 V   | 101         | -   | I <sub>VTRK_MAX</sub> | mA         |
|                        | V <sub>TH_OVTRK</sub>                            | V threshold over voltage VTRK        | Ramp on tracking output   | 5.3         | -   | -                     | V          |
|                        | SVR_VTRK   | Supply voltage tracking<br>rejection | C <sub>out</sub> = 4.7 $\mu$ F; VDD5 = 5 V<br>4 Vpp, VB mean 9 V,<br>f = 20 kHz | 40          | -   | -                     | dB         |
|                        | R <sub>ds_on</sub>                               | -                                    | VB = 4.8 V;<br>I <sub>VTRK1,2</sub> = 100 mA                                    | -           | -   | 3600                  | m $\Omega$ |
|                        | V <sub>os</sub>                                  | Over shoot during power up           | Cl <sub>oad</sub> $\geq$ 470 nF tested with<br>1 $\mu$ F                        | -           | -   | 5.5                   | V          |
|                        | Cl <sub>oad</sub> < 470 nF tested with<br>100 nF |                                      | -   | -           | 6   | V                     |            |
| V <sub>ov_filter</sub> | Overvoltage filter time                          | Test by scan                         | 48  | 64          | 80  | $\mu$ s               |            |

## 6.7 Main relay driver

Figure 22. Main relay driver controlled by L9779WD-SPI



### 6.7.1 Main relay driver functionality description

Main relay driver MRD is controlled by L9779WD-SPI depending on the voltage levels at pins KEY\_ON, VB and the power latch mode set by the  $\mu\text{C}$  as described in the previous sections.

The output stage MRD for main-relay-control is realized with a low-side-switch with integrated clamping at VCL voltage realized with a zener diode.

When VB is present ( $\text{VB} > \text{VB\_LV}$ ) the MRD driver is protected, in ON condition, against the over temperature fault. When the temperature is above junction the MRD is switched off. After  $\theta_{\text{HYSTERESIS}}$  the MRD returns to normal operation automatically.

In case of MRD short to battery without VB present i.e. during start-up sequence, when the current exceeds the IOVC value, this pin will be switched off after a certain filter time  $T_{\text{FILTEROVC}}$ ; to turn on MRD again it is necessary a high to low transition on KEY\_ON pin. Refer to scenario 5 ([Figure 29](#)).

In case of MRD short to battery with VB present i.e. during normal mode, when the current exceeds the IOVC value, this pin will be switched off after a certain filter time  $T_{\text{FILTEROVC}}$ ; the  $\mu\text{C}$  can try to turn on the MRD using the command MRD\_REACT until the VB voltage is above VB\_UV. Below this threshold the MRD retries to switch on, then if the fault is still present the MRD switches off and to turn it on again it is necessary a high to low transition on KEY\_ON pin. Refer to scenario 6-7-8 ([Figure 30](#), [31](#) and [32](#)).

In every condition the bit MRD\_OVC reports that the MRD is currently off due to a previous over current event.

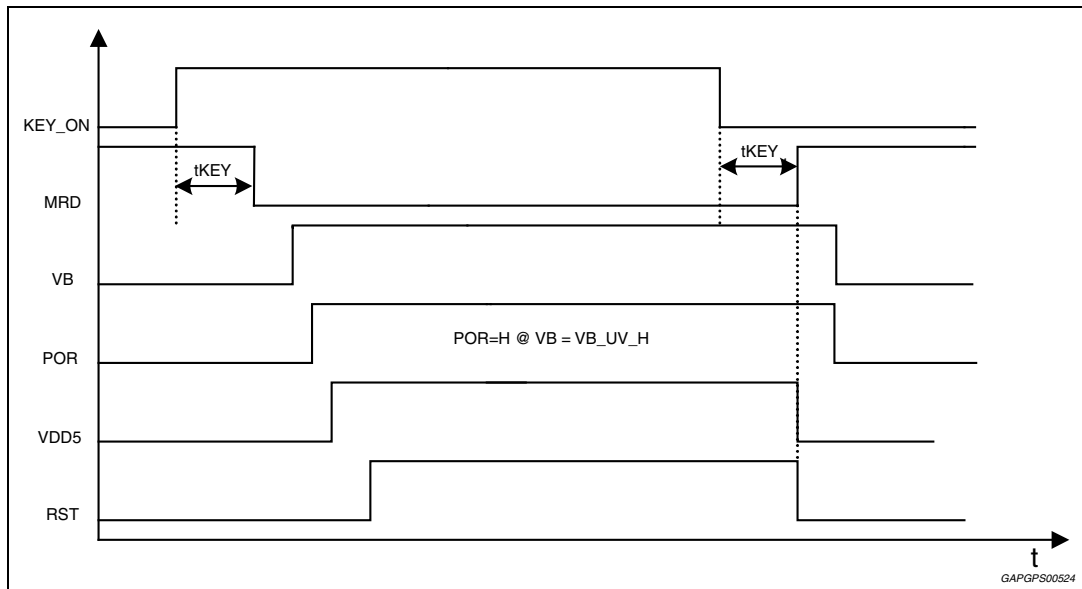
Diagnosis of MRD short to ground may be done as described in the power up/down management unit, switching off the MRD keeping alive all other regulators.

Table 17. Main relay driver electrical characteristics

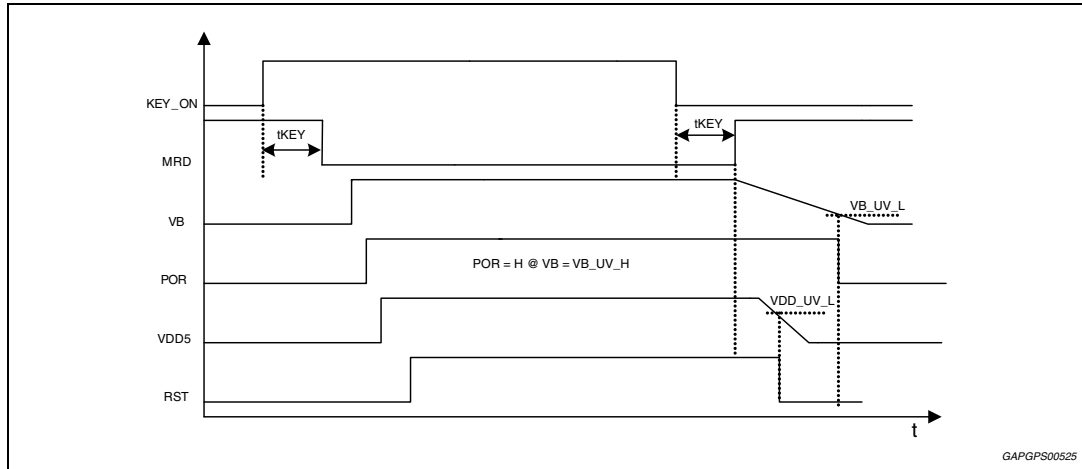
| Pin | Symbol           | Parameter                                | Test condition  | Min  | Typ | Max  | Unit                   |
|-----|------------------|--|---|------|-----|------|------------------------|
| MRD | $R_{DS-on}$      | Drain –source resistance                 | $I_{load} = 0.4\text{ A}; V_{bat} = 0 \text{ \& } 13.5\text{ V}$          | -    | -   | 2.4  | $\Omega$               |
|     | $I_{OUT,IK MRD}$ | Output leakage current                   | $V_{pin} = 13.5\text{ V}; V_{bat} = 0 \text{ \& } 13.5\text{ V}$          | -    | -   | 10   | $\mu\text{A}$          |
|     | VS/R             | Voltage S/R on/off                       | $R = 21\ \Omega, C = 10\text{ nF}; V_{bat} = 0 \text{ \& } 13.5\text{ V}$ | 1    | -   | 10   | $\text{V}/\mu\text{s}$ |
|     | Vcl              | Output clamping voltage                  | $V_{bat} = 0 \text{ \& } 13.5\text{ V}$                                   | 42   | -   | 55   | V                      |
|     | $I_{max}$        | Output current                           | Design info   |      | -   | 0.6  | A                      |
|     | IOVC             | Over current threshold                   | $V_{bat} = 0 \text{ \& } 13.5\text{ V}$                                   | 0.7  | -   | 1.4  | A                      |
|     | TFILTEROVC       | Over current filtering time              | Test by SCAN  | 5.25 | 7   | 8.75 | $\mu\text{s}$          |
|     | VB_UV            | VB threshold for MRD active              | $V_{bat} = 0 \text{ \& } 13.5\text{ V}$                                   | -    | -   | 4.15 | V                      |
|     | $PW_{clampSP}$   | Clamp single pulse ATE test              | $I_{load} = 0.5\text{ A};$ single pulse test                              | -    | -   | 15   | mJ                     |
|     | $PW_{clampRP}$   | Clamp repetitive pulses reliability test | $I_{load} = 0.25\text{ A}$<br>Freq =1 Hz; 1 Mpulse                        | -    | -   | 4    | mJ                     |

6.7.2 MRD scenarios

Figure 23. Scenario 1a: Standard on/off MRD driver with NO power latch mode bit P<sub>SOFF</sub> = 0

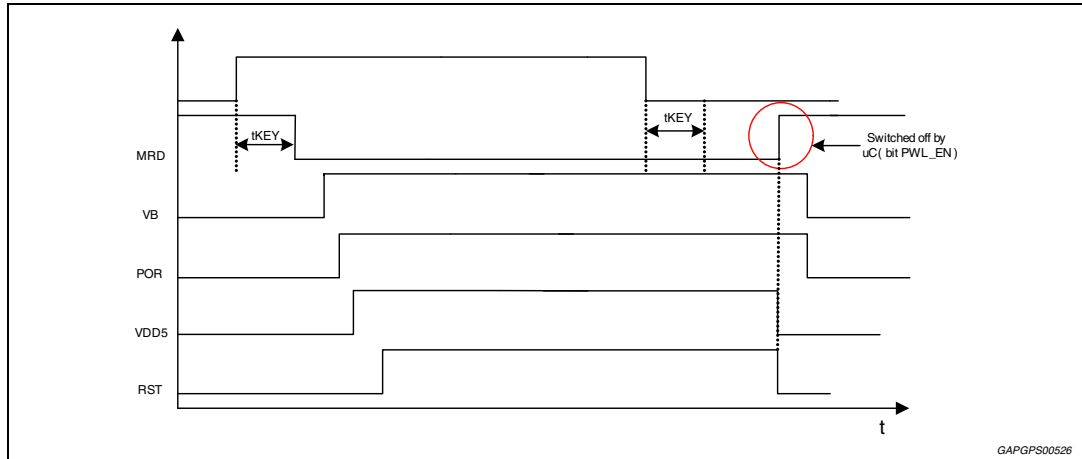


**Figure 24. Scenario 1b: Standard on/off MRD driver with NO power latch mode bit PSOFF = 1**



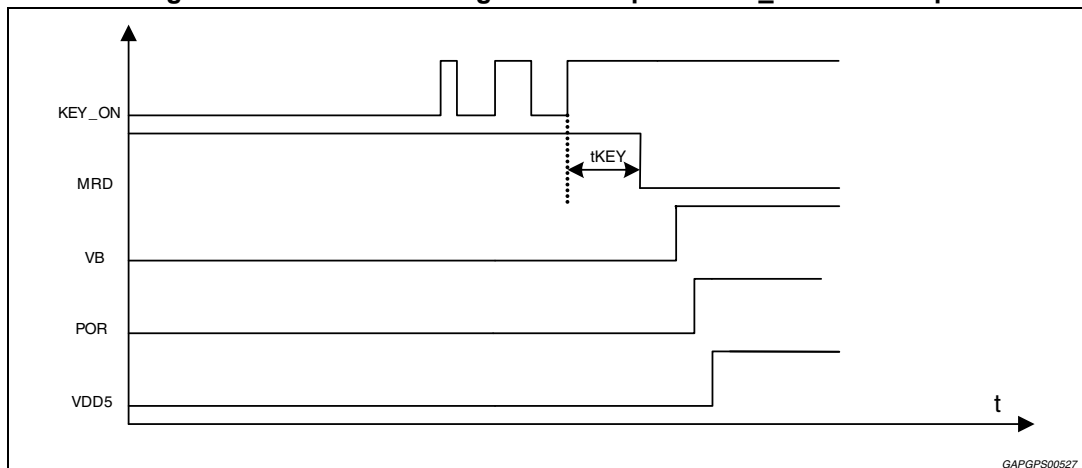
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**Figure 25. Scenario 2: Standard on/off MRD driver with power latch mode bit PSOFF = 0**



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**Figure 26. Scenario 3a: Deglitch concept on KEY\_ON at start-up**



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Figure 27. Scenario 3b: Deglitch concept on KEY\_ON during ON phase

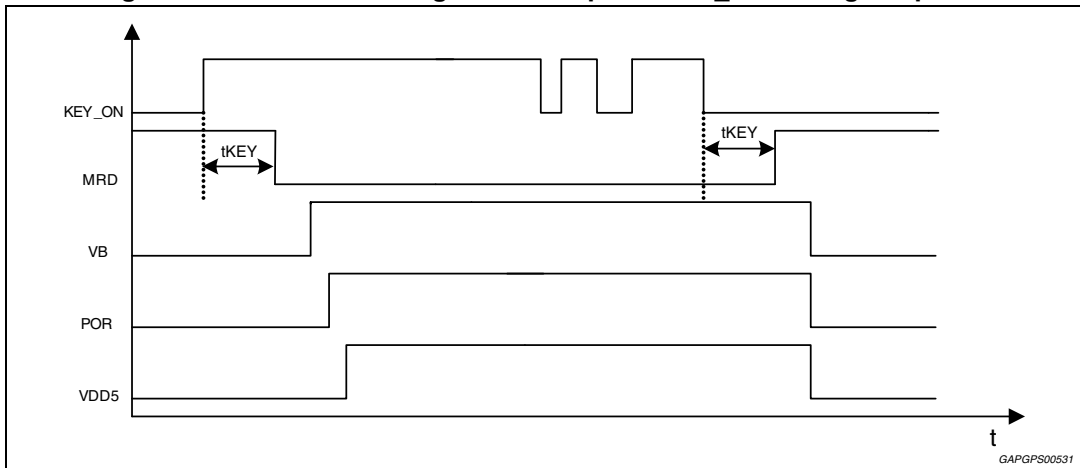


Figure 28. Scenario 4: Non standard on, KEY\_ON removed before VB present

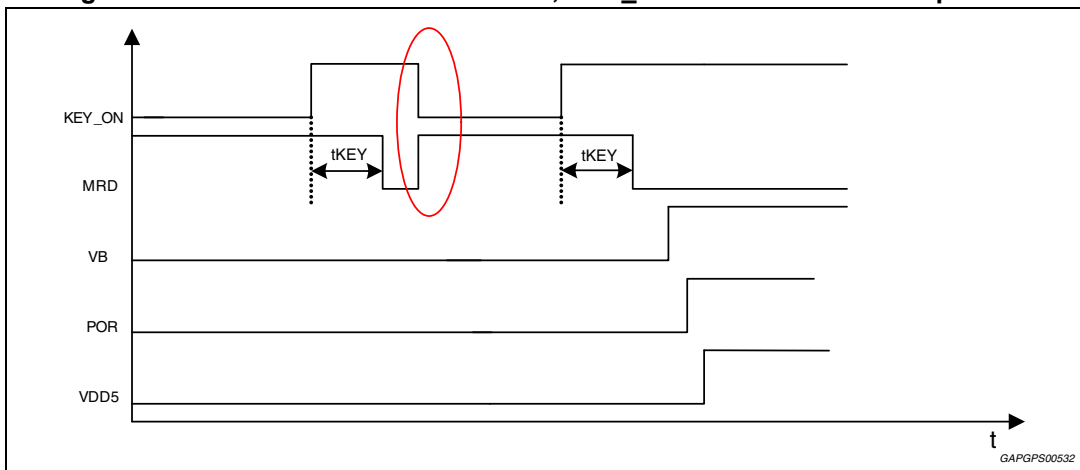


Figure 29. Scenario 5: MRD overcurrent without VB

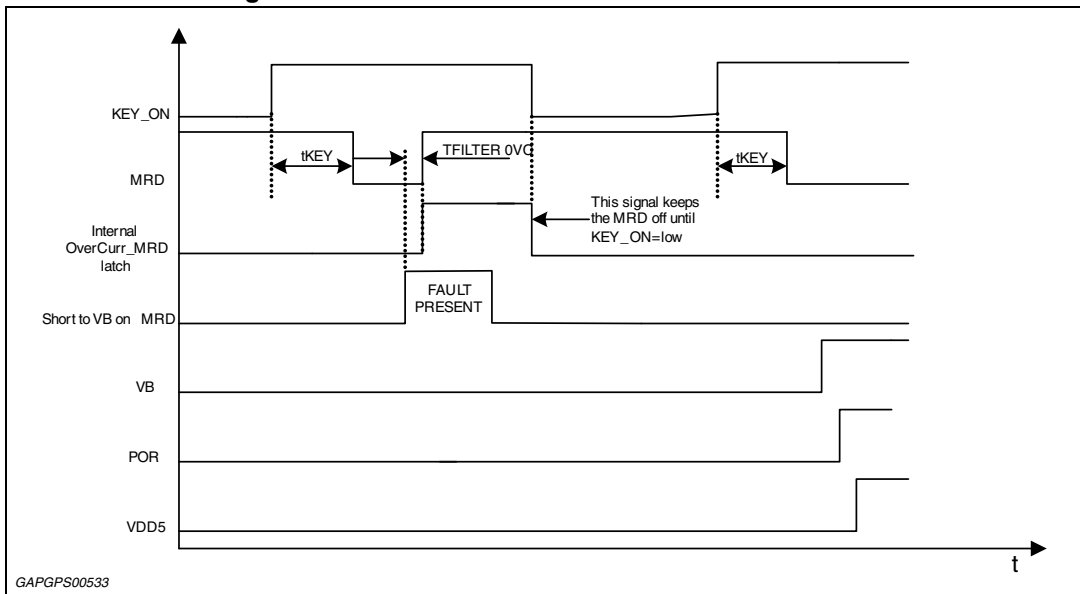


Figure 30. Scenario 6: permanent MRD overcurrent with VBPOR restart

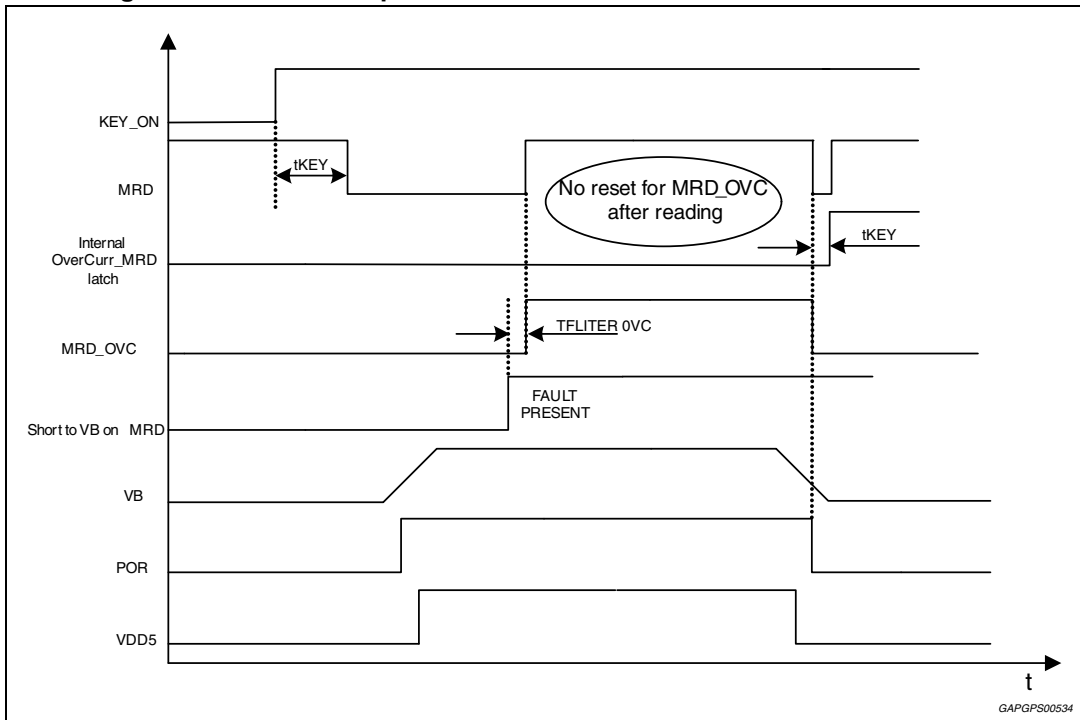


Figure 31. Scenario 7 (temporary MRD overcurrent with VB POR restart)

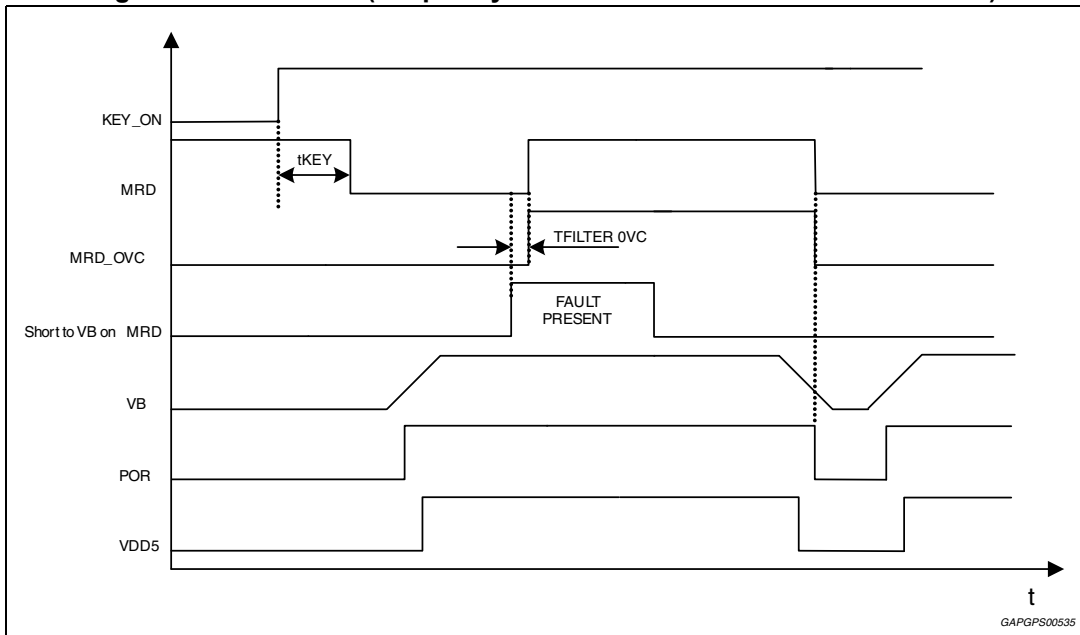
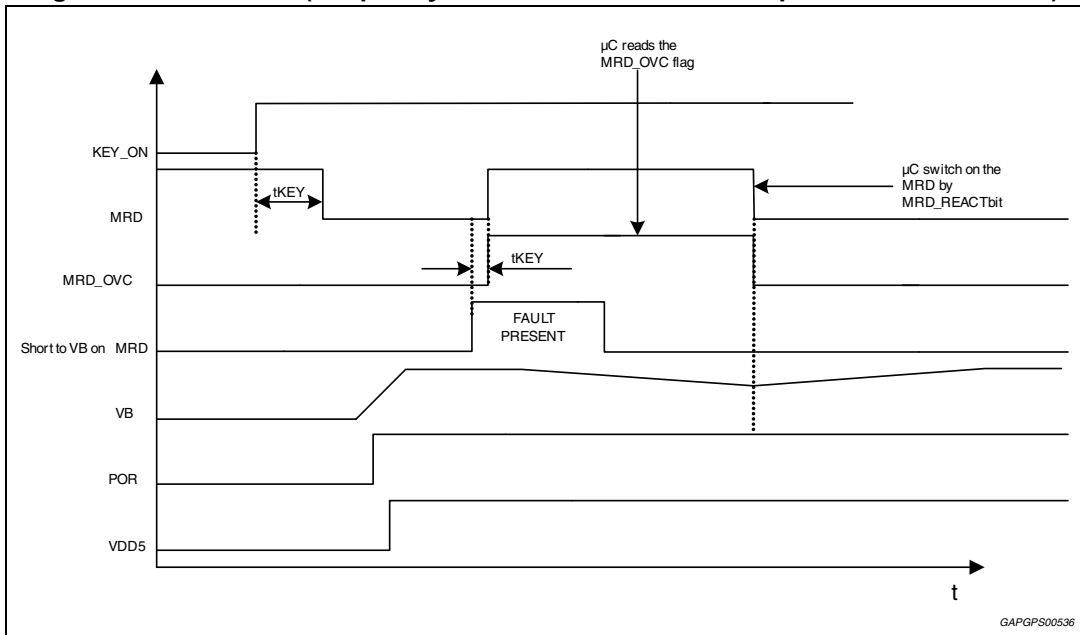




Figure 32. Scenario 8 (temporary MRD overcurrent with VB  $\mu$ C commands restart)

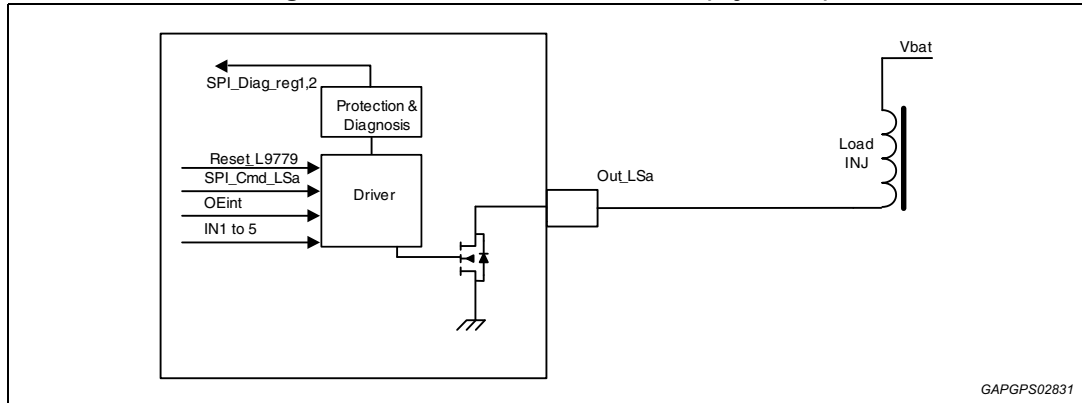


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## 6.8 Low-side switch function (LSa, LSb, LSd)

### 6.8.1 LSa function OUT 1 to 5 (Injectors)

Figure 33. LSa function OUT 1 to 5 (Injectors)



#### LSa functionality description

LSa are 5 protected low-side drivers with diagnosis and over current protection circuit.

They are driven by logical-AND of SPI control bit and dedicated parallel input IN1...IN5.

The maximum current for OUT1 to 4 is 2.2 A while for OUT5 is 3 A.

When Reset\_L9779 signal or OUT\_DIS bit is asserted OUT\_LSa is switched off.

When an over current fault occurs, the driver switches off with faster slew rate in order to reduce the power dissipation.

The turn on/off time is fixed and the slew-rate is controlled.

Max Cloud = 20 nF.

Table 18. LSa electrical characteristics

| Pin           | Symbol                    | Parameter                               | Test condition  | Min | Typ | Max  | Unit |
|---------------|---------------------------|---|---|-----|-----|------|------|
| OUT<br>1 to 5 | R <sub>DS-on</sub> LSa    | Drain source resistance                 | I <sub>load</sub> = 1.25 A                              | -   | -   | 0.72 | Ω    |
|               | I <sub>OUT_ik</sub>       | Output leakage current                  | V <sub>pin</sub> = 13.5 V                               | -   | -   | 10   | μA   |
|               | VS/R                      | Voltage S/R on/off                      | Load: 8 Ω, 10 nF<br>From 80% to 30% of V <sub>OUT</sub> | 2   | -   | 6    | V/μs |
|               | VS/R GateKill             | FAST VR/S off when an OVC fault happens | Load: 8 Ω, 10 nF<br>From 80% to 30% of V <sub>OUT</sub> | 5   | -   | 20   | V/μs |
|               | T <sub>Turn-on_LSa</sub>  | Turn-on delay time                      | From command to 80% V <sub>OUT</sub> , Load: 8 Ω, 10 nF | -   | -   | 6    | μs   |
|               | T <sub>Turn-off_LSa</sub> | Turn-off delay time                     | From command to 30% V <sub>OUT</sub> , Load: 8 Ω, 10 nF | -   | -   | 6    | μs   |
|               | V <sub>cl</sub>           | Output clamping voltage                 | I <sub>load</sub> = 1.25 A                              | 53  | 58  | 63   | V    |
|               | PW <sub>clampSP</sub>     | Clamp single pulse ATE test             | I <sub>load</sub> = 1.25 A single pulse                 | -   | -   | 25   | mJ   |

Table 18. LSA electrical characteristics (continued)

| Pin                | Symbol  | Parameter  | Test condition   | Min | Typ  | Max | Unit |
|--------------------|---|--|--|-----|------|-----|------|
| OUT<br>1 to 4      | PW <sub>clampRP</sub>   | Clamp repetitive pulses<br>Freq = 50 Hz (to be verified) | Tc ≤ 30°C; I <sub>OUT_n</sub> ≤ 1.8 A<br>13 Mio cycles   | -   | -    | 7.5 | mJ   |
|                    |   |  | Tc ≤ 65°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>130 Mio cycles  | -   | -    | 4   |      |
|                    |   |  | Tc ≤ 80°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>214 Mio cycles  | -   | -    | 4   |      |
|                    |   |  | Tc ≤ 100°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>175 Mio cycle  | -   | -    | 4   |      |
|                    |   |  | Tc ≤ 115°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>45 Mio cycle   | -   | -    | 4   |      |
|                    |   |  | Tc ≤ 130°C; I <sub>out_n</sub> ≤ 1.0 A<br>65 Mio cycle   | -   | -    | 3   |      |
|                    |   |  | Tc ≤ 145°C; I <sub>out_n</sub> ≤ 1.0 A<br>6 Mio cycle    | -   | -    | 3   |      |
| Reverse<br>voltage | Body diode reverse current<br>voltage drop (valid for OUT5<br>also) | I = -2.2 A   | -0.5   | -   | -1.2 | V   |      |
| OUT5               | PW <sub>clampSP</sub>   | Clamp single pulse                                       | I <sub>load</sub> = 1.25 A single pulse                  | -   | -    | 25  | mJ   |
|                    | PW <sub>clampRP</sub>   | Clamp repetitive pulses<br>Freq = 30 Hz                  | Tc < 30°C; I <sub>OUT5</sub> < 0.7 A<br>21 Mio cycles    | -   | -    | 17  |      |
|                    |   |  | Tc < 65°C; I <sub>OUT5</sub> < 0.7 A<br>70 Mio cycles    | -   | -    | 14  |      |
|                    |   |  | Tc < 80°C; I <sub>OUT5</sub> < 0.7 A<br>115.5 Mio cycles | -   | -    | 14  |      |
|                    |   |  | Tc < 90°C; I <sub>OUT5</sub> < 0.7 A<br>63 Mio cycles    | -   | -    | 14  |      |
|                    |   |  | Tc < 100°C; I <sub>OUT5</sub> < 0.7 A<br>31.5 Mio cycles | -   | -    | 14  |      |
|                    |   |  | Tc < 105°C; I <sub>OUT5</sub> < 0.7 A<br>10.5 Mio cycles | -   | -    | 14  |      |
|                    |   |  | Tc < 110°C; I <sub>OUT5</sub> < 0.7 A<br>7 Mio cycles    | -   | -    | 14  |      |
|                    |   |  | Tc < 115°C; I <sub>OUT5</sub> < 0.7 A<br>5.95 Mio cycles | -   | -    | 14  |      |
|                    |   |  | Tc < 120°C; I <sub>OUT5</sub> < 0.7 A<br>5.25 Mio cycles | -   | -    | 12  |      |
|                    |   |  | Tc < 125°C; I <sub>OUT5</sub> < 0.7 A<br>4.9 Mio cycles  | -   | -    | 12  |      |
|                    |   |  | Tc < 130°C; I <sub>OUT5</sub> < 0.7 A<br>4.55 Mio cycles | -   | -    | 12  |      |

**Table 18. LSA electrical characteristics (continued)**

| Pin  | Symbol                | Parameter                               | Test condition   | Min | Typ | Max | Unit |
|------|-----------------------|---|--|-----|-----|-----|------|
| OUT5 | PW <sub>clampRP</sub> | Clamp repetitive pulses<br>Freq = 30 Hz | Tc < 135°C; I <sub>OUT5</sub> < 0.7 A<br>4.55 Mio cycles | -   | -   | 12  | mJ   |
|      |                       |   | Tc < 140°C; I <sub>OUT5</sub> < 0.7 A<br>3.5 Mio cycles  | -   | -   | 12  |      |
|      |                       |   | Tc < 145°C; I <sub>OUT5</sub> < 0.7 A<br>3.5 Mio cycles  | -   | -   | 12  |      |

**Table 19. LSA diagnosis electrical characteristics**

| Pin           | Symbol                     | Parameter   | Test condition           | Min                         | Typ | Max                         | Unit |
|---------------|----------------------------|---|--------------------------|-----------------------------|-----|-----------------------------|------|
| OUT<br>1 to 5 | R <sub>open load</sub>     | Min resistor value open load detection              | Not tested               | 500                         | -   | -                           | kΩ   |
|               | I <sub>max</sub>           | Output current                                      | Not tested               | -                           | 2.2 | -                           | A    |
|               | I <sub>OV</sub>            | Over current threshold                              | -                        | 3                           | -   | 6                           | A    |
|               | T <sub>FILTEROV</sub>      | Over current filtering time                         | Tested by scan           | 2                           | 3   | 4                           | μs   |
|               | T <sub>FILTERdiagoff</sub> | Filtering open load and short to gnd diag. off      | Tested by scan           | 35                          | 50  | 65                          | μs   |
|               | T <sub>d_mask</sub>        | Diagnosis Mask time after switch-off                | Tested by scan           | 300                         | -   | 500                         | μs   |
|               | V <sub>HVT</sub>           | Open load threshold voltage                         | -                        | V <sub>Outopen</sub> +120mV | -   | 3                           | V    |
|               | V <sub>Outopen</sub>       | Open load output voltage                            | Open load condition      | 2.3                         | -   | 2.7                         | V    |
|               | V <sub>LVT</sub>           | Output short-circuit to GND voltage range threshold | -                        | 1.9                         | -   | V <sub>Outopen</sub> -200mV | V    |
| OUT<br>1 to 5 | I <sub>OUT_PD</sub>        | Output diagnostic pull down current Off state       | V <sub>pin</sub> = 5 V   | 50                          | -   | 110                         | μA   |
|               | I <sub>OUT_PU</sub>        | Output diagnostic pull up current Off state         | V <sub>pin</sub> = 1.5 V | 110                         | 160 | 210                         | μA   |
|               | I <sub>topen</sub>         | Open load threshold current                         | -                        | 30                          | -   | 90                          | μA   |

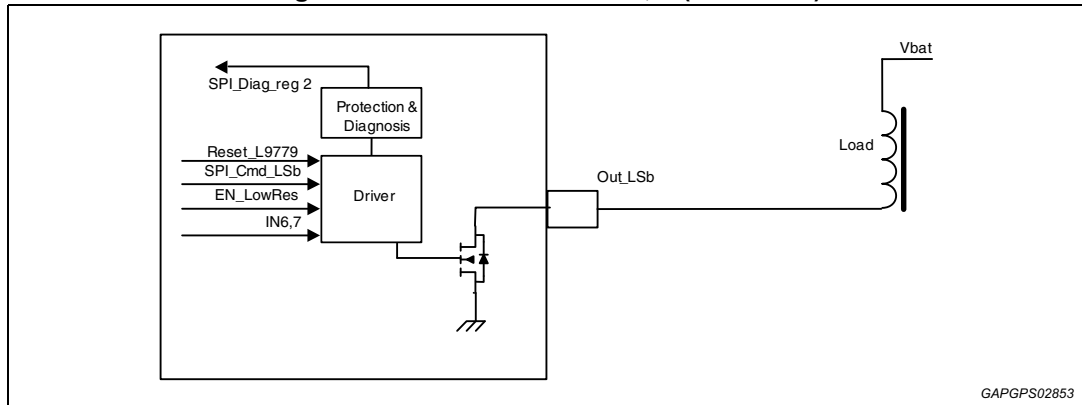
For OUT 5 only the following parameters are different respect to OUT1 to 4.

**Table 20. LSA diagnosis electrical characteristics (OUT 5)**

| Pin   | Symbol           | Parameter              | Test condition | Min | Typ | Max | Unit |
|-------|------------------|------------------------|----------------|-----|-----|-----|------|
| OUT 5 | I <sub>max</sub> | Output current         | Not tested     | -   | 3   | -   | A    |
|       | I <sub>OV</sub>  | Over current threshold | -              | 3.7 | -   | 6.9 | A    |

6.8.2 LSb function OUT6, 7 (O2 heater)

Figure 34. LSb function OUT6, 7 (O2 heater)



LSb functionality description

LSb are 2 protected low-side drivers with diagnosis and over current protection circuit.

They are driven by logical-AND of SPI control bit and dedicated parallel input IN6, IN7.

The turn on/off time is fixed and the slew-rate is controlled.

When an over current fault occurs, the driver switches off with faster slew rate in order to reduce the power dissipation.

The turn on/off time is fixed and the slew-rate is controlled.

Max Cload = 20 nF.

Table 21. LSb electrical characteristics

| Pin                   | Symbol                      | Parameter                               | Test condition  | Min  | Typ | Max  | Unit |
|-----------------------|-----------------------------|---|---|------|-----|------|------|
| OUT 6, 7              | R <sub>DS-on</sub> LSb      | Drain source resistance                 | T = -40°C, I <sub>load</sub> = 3 A                          | 0.05 | -   | 0.16 | Ω    |
|                       |                             |   | T = 25°C, I <sub>load</sub> = 3 A                           | 0.13 | -   | 0.23 | Ω    |
|                       |                             |   | T = 130°C, I <sub>load</sub> = 3 A                          | 0.21 | -   | 0.47 | Ω    |
|                       | I <sub>OUTIk</sub>          | Output leakage current                  | -   | -    | -   | 10   | μA   |
|                       | VS/R                        | Voltage S/R on/off                      | R = 4.5 Ω, C = 10 nF<br>From 80% to 30% of V <sub>OUT</sub> | 0.5  | -   | 2.5  | V/μs |
|                       | VS/R GateKill               | FAST VR/S off when an OVC fault happens | Load: 8 Ω, 10 nF<br>From 80% to 30% of V <sub>OUT</sub>     | 5    | -   | 20   | V/μs |
|                       | T <sub>Turn-on</sub> _LSb   | Turn-on delay time                      | From command to 80% V <sub>OUT</sub><br>Load: 4.5 Ω, 10 nF  | -    | -   | 7.5  | μs   |
|                       | T <sub>Turn-off</sub> _LSb  | Turn-off delay time                     | From command to 20% V <sub>OUT</sub><br>Load: 4.5 Ω, 10 nF  | -    | -   | 7.5  | μs   |
|                       | V <sub>Cl</sub>             | Output clamping voltage                 | I <sub>load</sub> = 1.5 A                                   | 41   | 45  | 49   | V    |
| PW <sub>clampSP</sub> | Clamp single pulse ATE test | I <sub>load</sub> = 1.5 A; single pulse | -   | -    | 25  | mJ   |      |

**Table 21. LSb electrical characteristics (continued)**

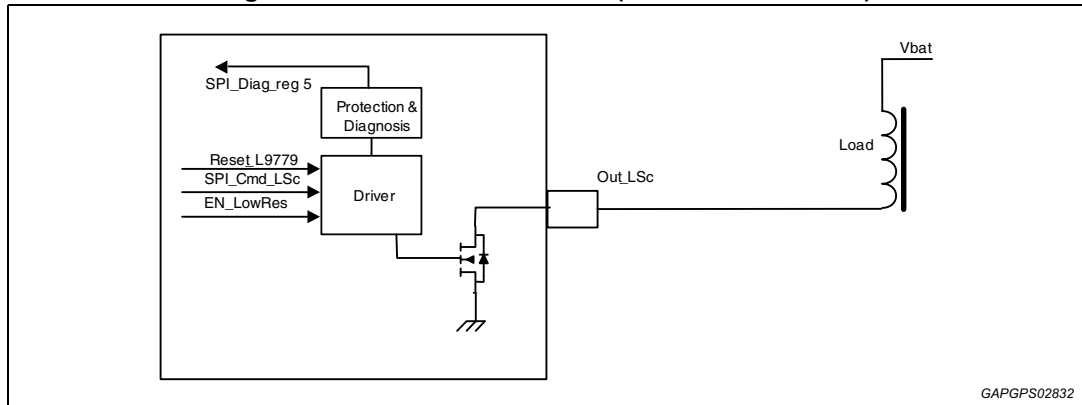
| Pin             | Symbol                                     | Parameter  | Test condition  | Min | Typ  | Max | Unit |
|-----------------|--|--|---|-----|------|-----|------|
| OUT 6, 7        | PW <sub>clampRP</sub>                      | Clamp repetitive pulses<br>Freq = 5 Hz Reliability<br>Test | T <sub>c</sub> ≤ 30 °C; I <sub>OUT_n</sub> ≤ 1.8 A<br>13 Mio cycles | -   | -    | 7.5 | mJ   |
|                 |  |  | T <sub>c</sub> ≤ 65°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>130 Mio cycles | -   | -    | 4   |      |
|                 |  |  | T <sub>c</sub> ≤ 80°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>214 Mio cycles | -   | -    | 4   |      |
|                 |  |  | T <sub>c</sub> ≤ 100°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>175 Mio cycle | -   | -    | 4   |      |
|                 |  |  | T <sub>c</sub> ≤ 115°C; I <sub>OUT_n</sub> ≤ 1.4 A<br>45 Mio cycle  | -   | -    | 4   |      |
|                 |  |  | T <sub>c</sub> ≤ 130°C; I <sub>OUT_n</sub> ≤ 1.0 A<br>65 Mio cycle  | -   | -    | 3   |      |
|                 |  |  | T <sub>c</sub> ≤ 145°C; I <sub>OUT_n</sub> ≤ 1.0 A<br>6 Mio cycle   | -   | -    | 3   |      |
| Reverse voltage | Body diode reverse<br>current voltage drop | I = -5 A   | -1.3  | -1  | -0.5 | V   |      |

**Table 22. LSb diagnosis electrical characteristics**

| Pin                 | Symbol   | Parameter   | Test condition         | Min                            | Typ  | Max                            | Unit |
|---------------------|--|---|------------------------|--------------------------------|------|--------------------------------|------|
| OUT6, 7             | I <sub>max</sub>                               | Output current                                    | Not tested             | -                              | 5    | -                              | A    |
|                     | I <sub>OVc</sub>                               | Over current threshold                            | T = -40°C              | 8.6                            | -    | 12.4                           | A    |
|                     |  |   | T = 25°C               | 8                              | -    | 11.2                           | A    |
|                     |  |   | T = 130°C              | 7.8                            | -    | 9.9                            | A    |
|                     | T <sub>FILTEROVc</sub>                         | Over current filtering time                       | Tested by scan         | 1.5                            | -    | 2.5                            | µs   |
|                     | T <sub>FILTERdiagoff</sub><br>f                | Filtering open load and short<br>to GND diag. off | Tested by scan         | 7                              | -    | 13                             | µs   |
|                     | T <sub>d_mask</sub>                            | Diagnosis mask delay after<br>switch-off          | Tested by scan         | 300                            | -    | 500                            | µs   |
|                     | V <sub>HVT</sub>                               | Open load threshold voltage                       | -                      | V <sub>Outopen</sub><br>+120mV | -    | 3                              | V    |
|                     | V <sub>Outopen</sub>                           | Open load output voltage                          | Open load condition    | 2.3                            | -    | 2.7                            | V    |
|                     | V <sub>LVT</sub>                               | Output short-circuit to GND<br>threshold voltage  | -                      | 1.9                            | -    | V <sub>Outopen</sub><br>-200mV | V    |
|                     | I <sub>OUT_PD</sub>                            | Output diagnostic pull down<br>current OFF STATE  | V <sub>pin</sub> = 5 V | 50                             | -    | 110                            | µA   |
| I <sub>OUT_PU</sub> | Output diagnostic pull up<br>current OFF STATE | V <sub>pin</sub> = 1.5 V                          | -210                   | -                              | -108 | µA                             |      |
| I <sub>topen</sub>  | Open load threshold current                    | -   | 30                     | -                              | 90   | µA                             |      |

### 6.8.3 LSc function OUT20 (low current drivers)

Figure 35. LSc function OUT20 (low current drivers)



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#### LSc functionality description

LSc is 1 protected Low-Side drivers with diagnosis and over current protection circuit. The off state diagnosis (open load and short to GND) detection can be switched off by OFF\_LCDR bit.

It is driven by logical-AND of SPI control bit for OUT20.

When Reset\_L9779 signal or OUT\_DIS bit is asserted OUT\_LSc is switched off.

When an over current fault occurs, the driver switches off with faster slew rate in order to reduce the power dissipation.

The turn on/off time is fixed. During turn-off the slope is fixed by external RC load.

Max Load = 20 nF.

Table 23. LSc electrical characteristics

| Pin   | Symbol              | Parameter                                | Test condition  | Min  | Typ | Max  | Unit          |
|-------|---------------------|--|---|------|-----|------|---------------|
| OUT20 | $R_{DS-on\ LSc}$    | Drain source resistance                  | $I_{load} = 50\text{ mA}$   | -    | -   | 20   | $\Omega$      |
|       | $I_{OUT\_lk}$       | Output leakage current                   | $V_{pin} = 13.5\text{ V @hot}$  | -    | -   | 10   | $\mu\text{A}$ |
|       | $T_{Turn-on\_LSb}$  | Turn-on delay time                       | From command to 80% $V_{OUT}$ ; Load: 250 $\Omega$ , 10 nF                                  | -    | -   | 5    | $\mu\text{s}$ |
|       | $T_{Turn-off\_LSb}$ | Turn-off delay time                      | From command to 30% $V_{OUT}$ ; Load: 250 $\Omega$ , 10 nF                                  | -    | -   | 5    | $\mu\text{s}$ |
|       | $V_{cl}$            | Output clamping voltage                  | $I_{load} = 50\text{ mA}$   | 40   | 45  | 50   | V             |
|       | $PW_{clampSP}$      | Clamp single pulse ATE test              | -   | -    | -   | 3.5  | mJ            |
|       | $PW_{clampRP}$      | Clamp repetitive pulses Reliability Test | $T_c \leq 145\text{ }^\circ\text{C}$ ;<br>$I_{OUT\_n} \leq 0.03\text{ A}$<br>0.5 Mio cycles | -    | -   | 0.2  | mJ            |
|       | Reverse voltage     | Body diode reverse current voltage drop  | $I = -50\text{ mA}$   | -0.5 | -1  | -1.1 | V             |

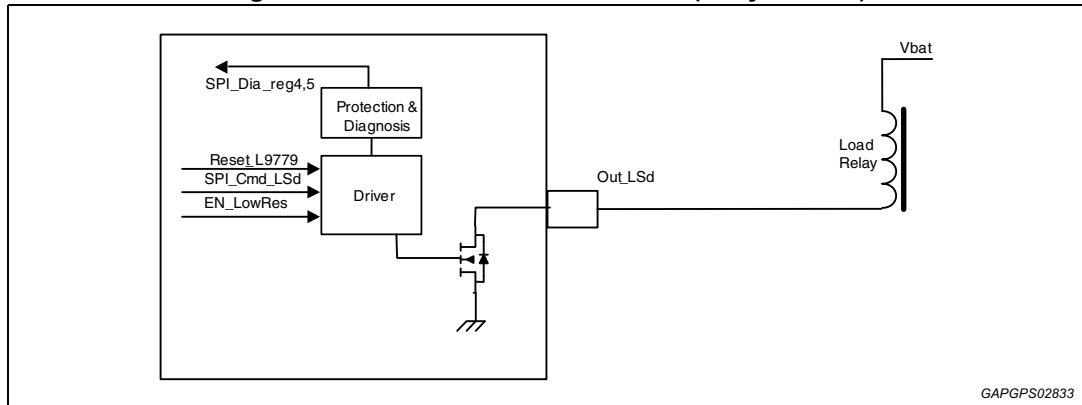
Table 24. LSc diagnosis electrical characteristics

| Pin   | Symbol              | Parameter                                      | Test condition                                     | Min                   | Typ | Max                   | Unit      |
|-------|---------------------|--|--|-----------------------|-----|-----------------------|-----------|
| OUT20 | $I_{OVC}$           | Over current threshold                         | -  | 70                    | -   | 130                   | mA        |
|       | $T_{FILTEROVC}$     | Over current filtering time                    | Tested by scan                                     | 2                     | 4   | 5                     | $\mu s$   |
|       | $T_{FILTERdiagoff}$ | Filtering open load and short to GND diag. off | Tested by scan                                     | 35                    | 50  | 65                    | $\mu s$   |
|       | $Td\_mask$          | Diagnosis mask delay after switch-off          | Tested by scan                                     | 300                   | -   | 500                   | $\mu s$   |
|       | $V_{HVT}$           | Open load threshold voltage                    | -  | $V_{Outopen} + 160mV$ | -   | 3                     | V         |
|       | $V_{Outopen}$       | Output open load voltage                       | -  | 2.3                   | -   | 2.7                   | V         |
|       | $V_{LVT}$           | Output short-circuit to GND threshold voltage  | -  | 1.9                   | -   | $V_{Outopen} - 200mV$ | V         |
|       | $I_{OUT\_PD}$       | Output diagnostic pull down current Off state  | $V_{pin} = 5 V$                                    | 50                    | -   | 110                   | $\mu A$   |
|       | $I_{OUT\_PU}$       | Output diagnostic pull up current Off state    | $V_{pin} = 1.5 V$                                  | 110                   | 160 | 210                   | $\mu A$   |
|       | $I_{topen}$         | Open load threshold current                    | -  | 30                    | -   | 110                   | $\mu A$   |
|       | $V_{S/R ON}$        | Voltage R On                                   | $R = 270 \text{ Ohm}$<br>$C_{load} = 10 \text{ F}$ | 2                     | -   | 6                     | $V/\mu s$ |
|       | $V_{S/R OFF}$       | Voltage R Off                                  | From 80% to 30% of $V_{OUT}$                       | 5                     | -   | 14                    | $V/\mu s$ |



### 6.8.4 LSd function OUT13 to 18 (relay drivers)

Figure 36. LSd function OUT13 to 18 (relay drivers)



#### LSd functionality description

LSd are 6 protected Low-Side drivers with diagnosis, and over current protection circuit.

They are driven via SPI interface.

When Reset\_L9779 signal or OUT\_DIS bit is asserted OUT\_LSd is switched off.

The turn on/off time is fixed and the slew-rate is controlled.

OUT13 and OUT14 are able to remain active also during crank pulse when the battery voltage on the VB pin goes below the level VB\_LV for a period of time THOLD, this time lapse calculation is triggered by the falling edge of RST. In this situation VDD5 is below undervoltage threshold (VDD\_UV) and the micro controller is in reset condition. During the THOLD time the VDD5 supply and the micro controller have to recover and take over control of the output. Otherwise the output is switched OFF after the THOLD time.

The low battery functionality can be enabled/disabled through bit OUT13\_EN\_LB and OUT14\_EN\_LB of CONF\_REG7.

Table 25. LSd electrical characteristics

| Pin             | Symbol              | Parameter                                    | Test condition   | Min | Typ | Max | Unit      |
|-----------------|---------------------|--|--|-----|-----|-----|-----------|
| OUT<br>13 to 18 | $R_{DS-on\ LSd}$    | Drain source resistance                      | $I_{load} = 0.6\ A$  | -   | -   | 1.5 | $\Omega$  |
|                 | $I_{OUT\ lk}$       | Output leakage current                       | $V_{pin} = 13.5\ V$  | -   | -   | 10  | $\mu A$   |
|                 | $V_{S/R}$           | Voltage S/R on/off                           | $R = 21\ \Omega, C = 10\ nF$<br>From 80% to 30% of $V_{OUT}$ | 2   | -   | 6   | $V/\mu s$ |
|                 | $V_{S/R\ GateKill}$ | FAST $V_{R/S}$ off when an OVC fault happens | Load: $8\ \Omega, 10\ nF$ ; From 80% to 30% $V_{OUT}$ ;      | 5   | -   | 30  | $V/\mu s$ |
|                 | $T_{Turn-on\ LSd}$  | Turn-on delay time                           | From command to 80% $V_{OUT}$<br>Load: $21\ \Omega, 10\ nF$  | -   | -   | 6   | $\mu s$   |
|                 | $T_{Turn-off\ LSd}$ | Turn-off delay time                          | From command to 30% $V_{OUT}$<br>Load: $21\ \Omega, 10\ nF$  | -   | -   | 6   | $\mu s$   |
|                 | $V_{cl}$            | Output clamping voltage                      | $I_{load} = 0.6\ A$  | 40  | 45  | 50  | V         |

**Table 25. LSd electrical characteristics (continued)**

| Pin             | Symbol                                  | Parameter   | Test condition   | Min | Typ  | Max | Unit |
|-----------------|---|---|--|-----|------|-----|------|
| OUT<br>13 to 18 | PW <sub>clampSP</sub>                   | Clamp single pulse ATE test   | I <sub>load</sub> = 0.6 A; single pulse                                | -   | -    | 15  | mJ   |
|                 | PW <sub>clampRP</sub>                   | Clamp repetitive pulses<br>Freq = 1 Hz (to be verified)<br>Reliability Test | T <sub>c</sub> ≤ 30 °C;<br>I <sub>OUT_n</sub> ≤ 0.45 A<br>1 Mio cycles | -   | -    | 6.5 | mJ   |
|                 |   |   | T <sub>c</sub> ≤ 80 °C;<br>I <sub>OUT_n</sub> ≤ 0.3 A<br>25 Mio cycle  | -   | -    | 6.5 |      |
|                 |   |   | T <sub>c</sub> ≤ 100°C;<br>I <sub>OUT_n</sub> ≤ 0.3A<br>20 Mio cycle   | -   | -    | 6.5 |      |
|                 |   |   | T <sub>c</sub> ≤ 130°C;<br>I <sub>OUT_n</sub> ≤ 0.3 A<br>5 Mio cycle   | -   | -    | 5.5 |      |
| Reverse voltage | Body diode reverse current voltage drop | I = -0.6 A  | -0.5   | -1  | -1.1 | V   |      |

Min/Max of Reverse Current will be added after BA characterization.

**Table 26. LSd diagnosis electrical characteristics**

| Pin             | Symbol                     | Parameter                                      | Test condition           | Min                         | Typ | Max                         | Unit |
|-----------------|----------------------------|--|--------------------------|-----------------------------|-----|-----------------------------|------|
| OUT<br>13 to 18 | R <sub>open load</sub>     | Min resistor value open load detection         | Not tested               | 500                         | -   | -                           | kΩ   |
|                 | I <sub>max</sub>           | Output current                                 | Not tested               | -                           | 0.6 | -                           | A    |
|                 | I <sub>OVC</sub>           | Over current threshold                         | -                        | 1                           | -   | 2                           | A    |
|                 | T <sub>FILTEROVC</sub>     | Over current filtering time                    | Tested by scan           | 2                           | 4   | 5                           | μs   |
|                 | T <sub>FILTERdiagoff</sub> | Filtering open load and short to GND diag. off | Tested by scan           | 35                          | 50  | 65                          | μs   |
|                 | T <sub>d_mask</sub>        | Diagnosis mask delay after switch-off          | Tested by scan           | 300                         | -   | 500                         | μs   |
|                 | V <sub>HVT</sub>           | Output voltage open load threshold             | -                        | V <sub>Outopen</sub> +120mV | -   | 3                           | V    |
|                 | V <sub>OUTOPEN</sub>       | Output open load voltage                       | Open load condition      | 2.3                         | -   | 2.7                         | V    |
|                 | V <sub>LVT</sub>           | Output short-circuit to GND threshold voltage  | -                        | 1.9                         | -   | V <sub>Outopen</sub> -200mV | V    |
|                 | I <sub>OUT_PD</sub>        | Output diagnostic pull down current off state  | V <sub>pin</sub> = 5 V   | 50                          | -   | 110                         | μA   |
|                 | I <sub>OUT_PU</sub>        | Output diagnostic pull up current off state    | V <sub>pin</sub> = 1.5 V | -210                        | -   | -108                        | μA   |

**Table 26. LSd diagnosis electrical characteristics (continued)**

| Pin          | Symbol             | Parameter   | Test condition | Min | Typ | Max  | Unit          |
|--------------|--------------------|---|----------------|-----|-----|------|---------------|
| OUT 13 to 18 | $I_{\text{topen}}$ | Open load threshold current                                 | -              | 30  | -   | 90   | $\mu\text{A}$ |
| OUT13, 14    | $T_{\text{HOLD}}$  | Switch on to off delay during low battery voltage operation | Tested by scan | 400 | -   | 800  | ms            |
|              | VB_UV              | VB voltage threshold for low battery function               | -              | -   | -   | 4.15 | V             |

**Figure 37. Behavior of OUT13, 14, 21, 25 with  $VB = VB_{UV}$  for a time shorter than  $T_{\text{hold}}$  and with a valid ON condition**

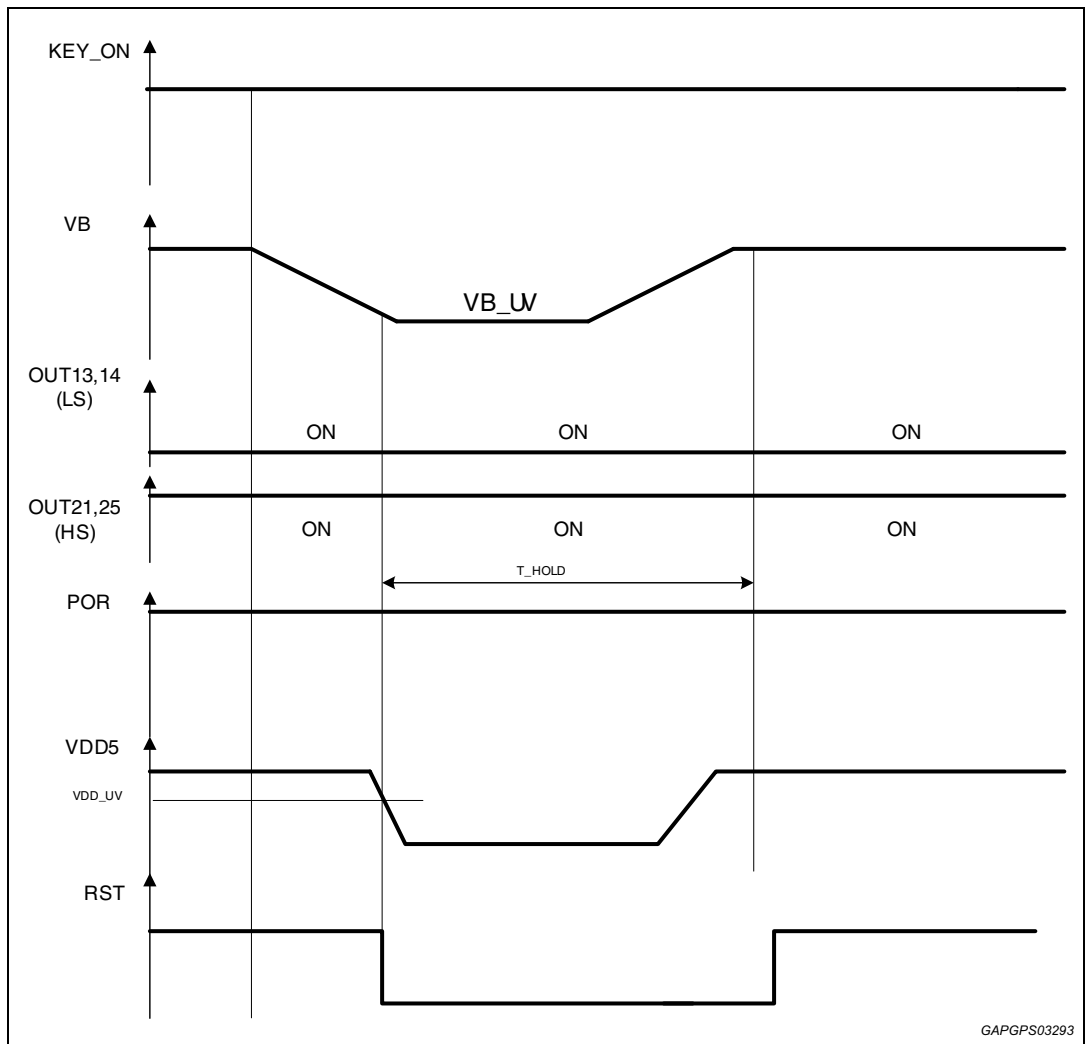


Figure 38. Behavior of OUT13, 14, 21, 25 with  $V_B = UB\_UV$  for a time longer than  $T_{hold}$  and with a valid ON condition

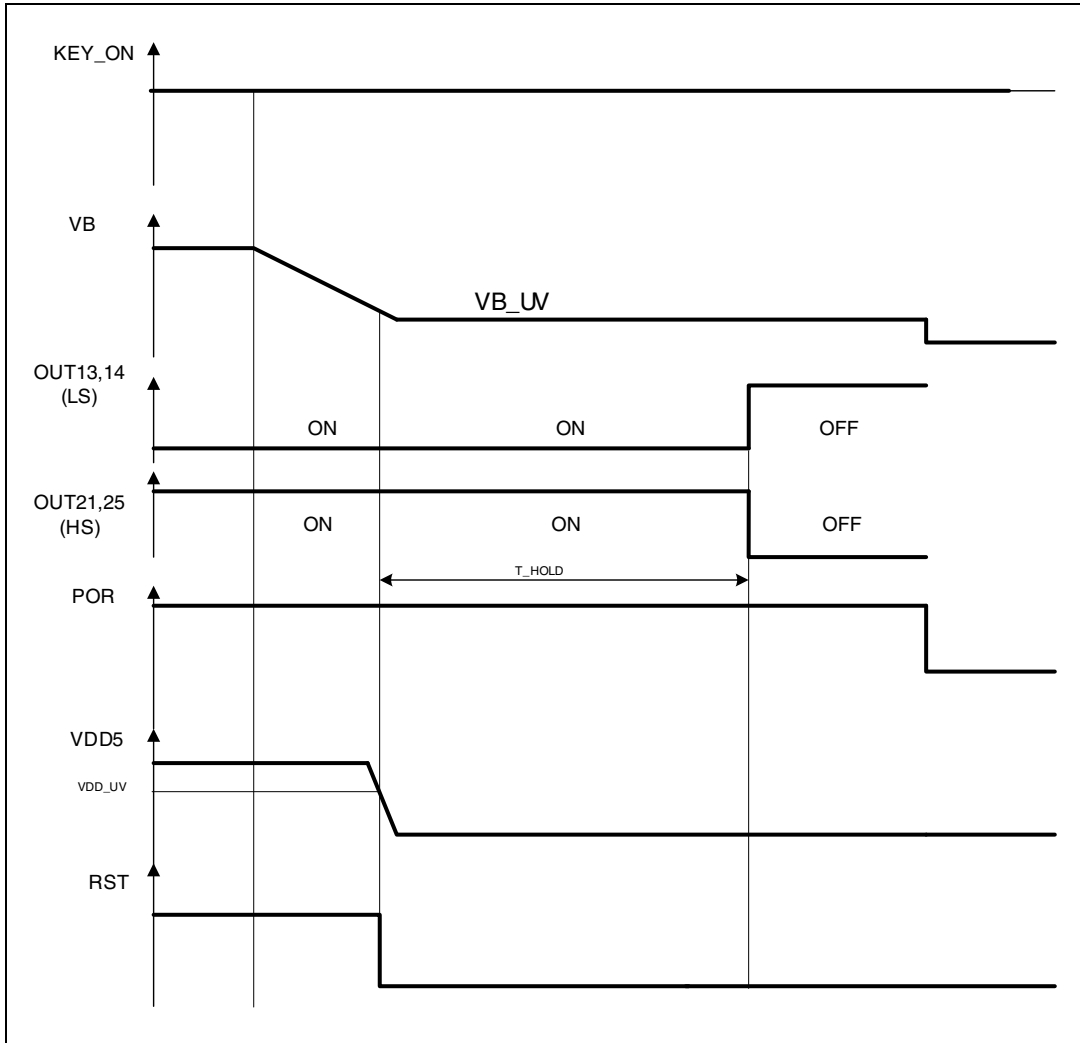
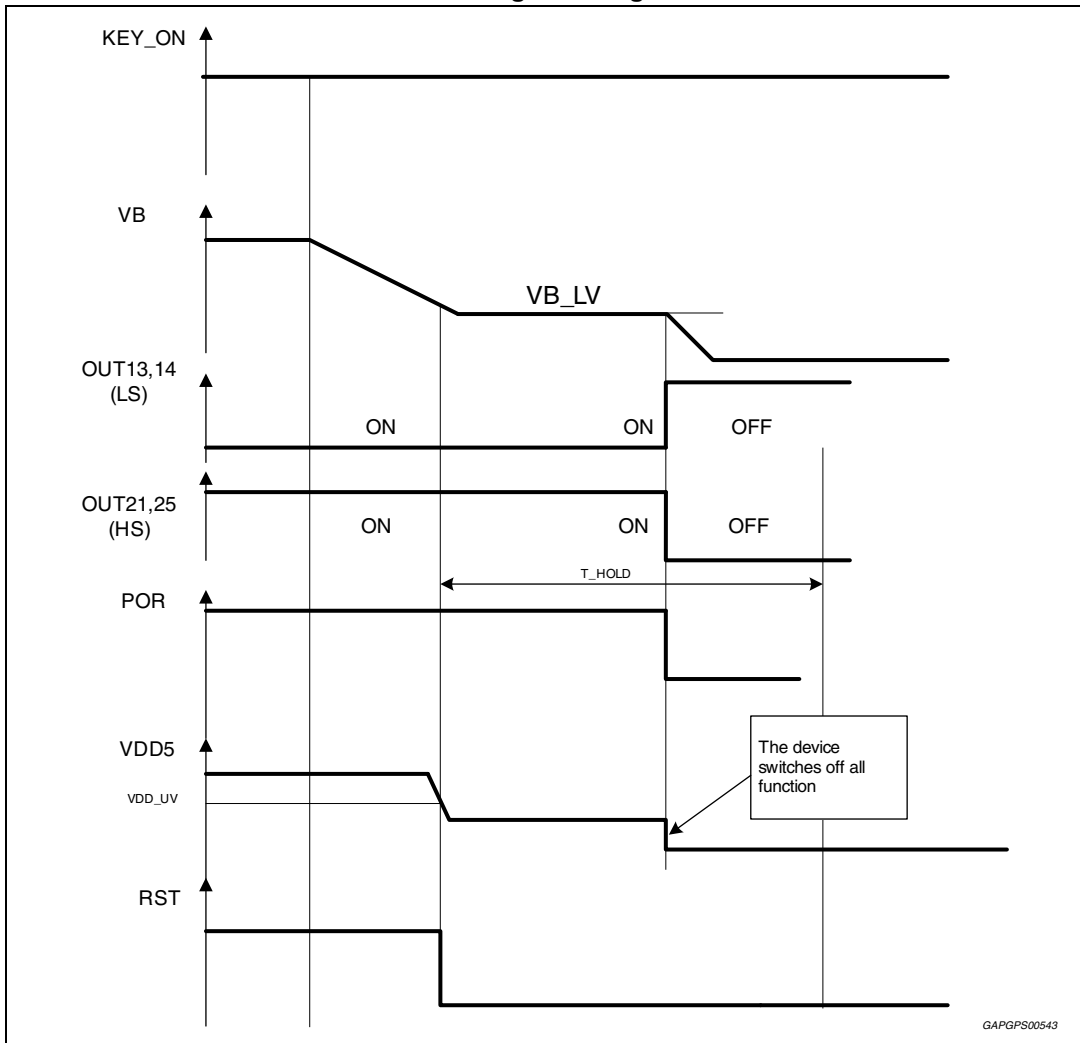


Figure 39. Behavior of OUT13, 14, 21, 25 with VB that drops lower than POR threshold during cranking



## 6.9 L<sub>Sa</sub>, L<sub>Sb</sub>, L<sub>Sc</sub>, L<sub>Sd</sub> diagnosis

Each channel locally detects and writes its own fault or no-fault condition (codified on 2 bit according to the table FAULT ENCODING CONDITION).

- short circuit to battery or overcurrent for all the outputs during ON condition.
- open load or short to GND during OFF condition.

The faults are latched and reset every Read Diag operation.

In OFF condition the first fault detected is latched and can be overwritten only by the ON condition fault.

### Channel “on”

#### Short to V<sub>b</sub>:

Current diagnosis is the result of a comparison between driver load current and internal IOVC thresholds.

If:  $I_{LOAD} > IOVC$  for  $t > T_{FILTEROVC}$  the driver is switched off and the fault is set, latched and reset every Read Diag operation.

When the fault occurs the driver is switched off with a controlled slew-rate.

The driver switches on AGAIN in the following conditions:

- If command goes LOW and then HIGH again
- If command remains active the driver is switched automatically on at every Read Diag operation.

#### Short to GND:

Not available.

#### Open Load:

Not available.

### Channel “off”

#### Short to V<sub>b</sub>:

Not available.

#### Short to GND & open load:

In open load condition an internal circuit drives the OUT<sub>x</sub> voltage to VOUT<sub>OPEN</sub> with a maximum pull-up/down current of IOU<sub>T</sub>\_PU and IOU<sub>T</sub>\_PD.

Diagnosis is done comparing driver output voltage with internal voltage thresholds VHVT and VLVT: if the voltage is below VLVT a short to GND is detected, if the voltage is above VLVT and below VHVT an open load is detected and if the voltage is above VHVT no fault is present.

Diagnosis status is masked for T<sub>d\_mask</sub> time after the off event occurs to allow the output voltage to reach the proper value.

Short to GND and open load are filtered with T<sub>FILTERdiagoff</sub> time.

Diag status is latched and reset at every Read Diag operation.

For LSc(OUT20) the IOOUT\_PD/IOOUT\_PU can be switched off by OFF\_LCDR bit and therefore the Open Load and Short To GND detections are not available.

Figure 40. LSx diagnosis circuit

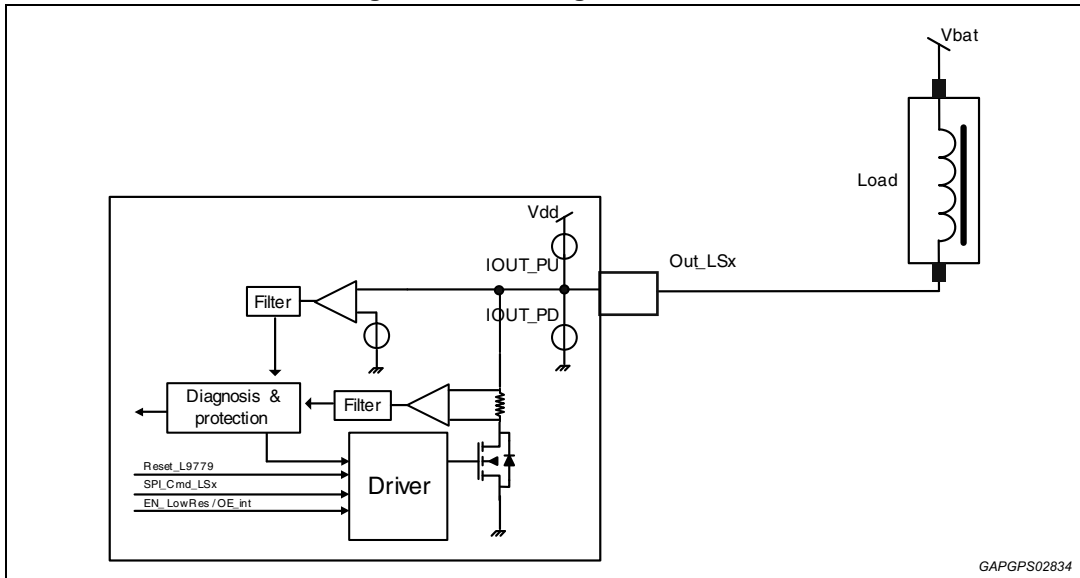


Table 27. Fault encoding condition

| Bit n+1 | Bit n | Description                          |
|---------|-------|--------------------------------------|
| 1       | 1     | Power stage OK no Fail               |
| 0       | 1     | Open Load OL                         |
| 1       | 0     | Short circuit to VB/over current SGB |
| 0       | 0     | Short circuit to GND SCG             |

Figure 41. Fault encoding condition diagram

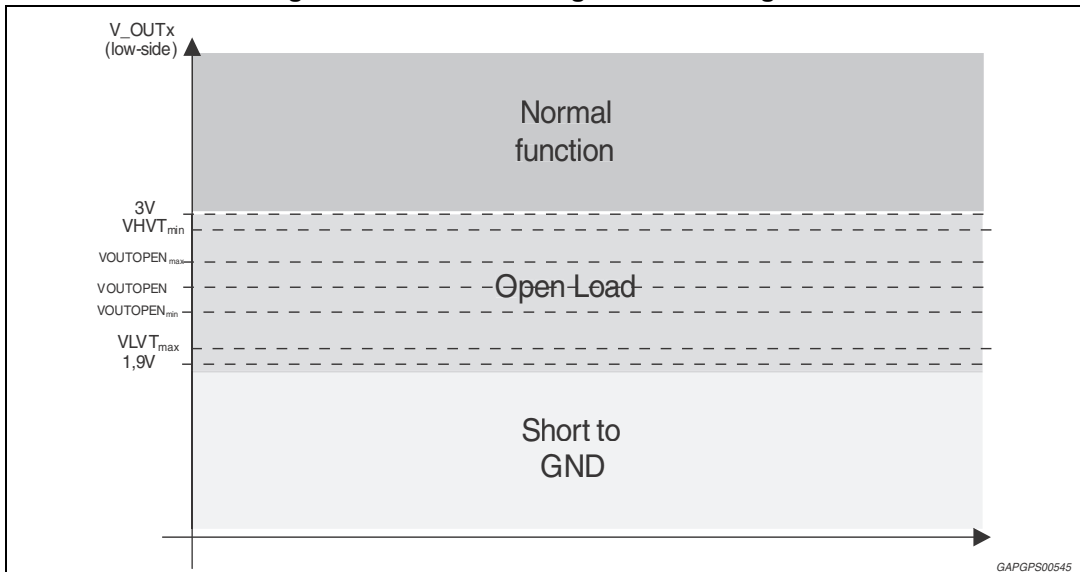
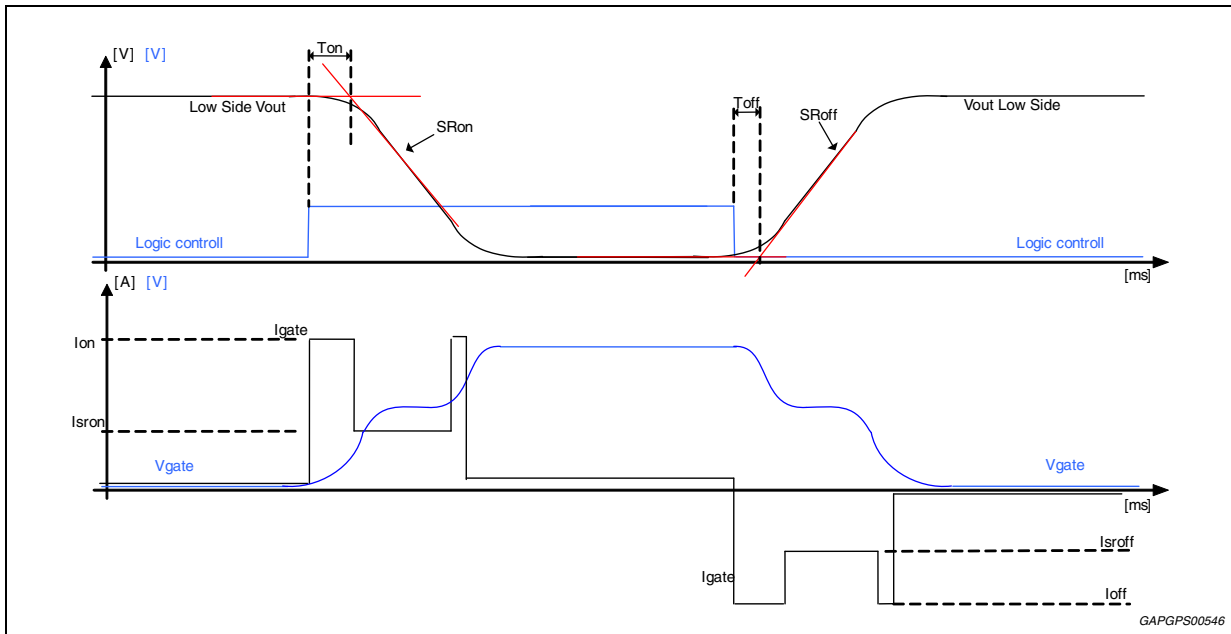


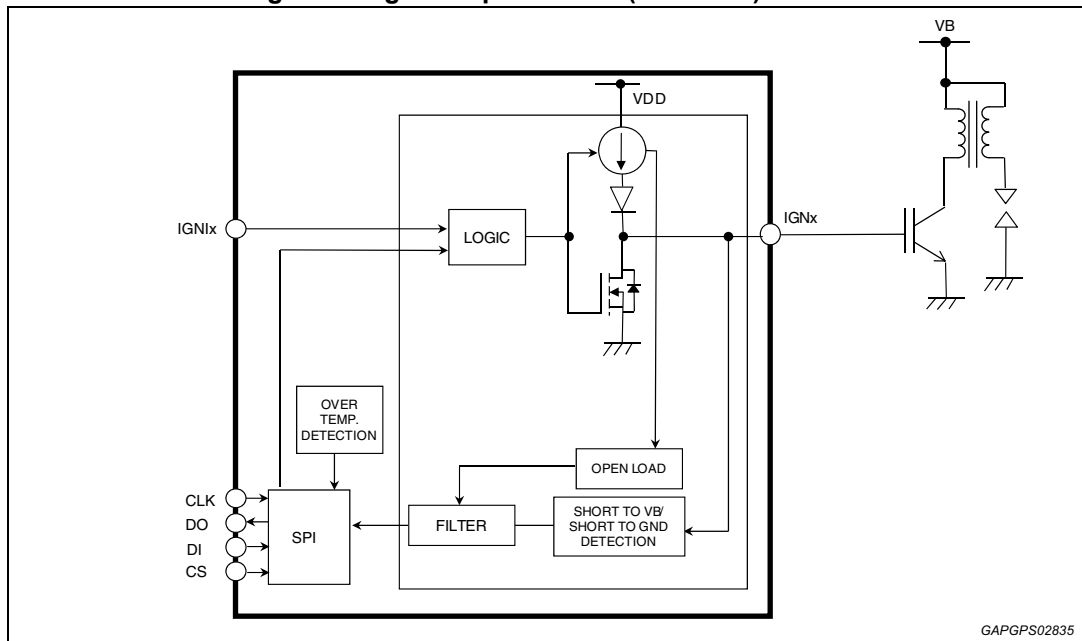
Figure 42. LSx ON/OFF slew rate control diagram



GAPGPS00546

## 6.10 Ignition pre-drivers (IGN1 to 4)

Figure 43. Ignition-pre drivers (IGN1 to 4) circuit



GAPGPS02835



### 6.10.1 Ignition pre-drivers functionality description

The 4 ignition pre-drivers are push-pull output with diagnosis and over current protection circuit. They can drive IGBT Darlingtons transistors.

The load is switched on with a current and switched off with I\_LS\_cont current.

They are driven by logical-AND of SPI control bit and dedicated parallel input IGN1...IGN4.

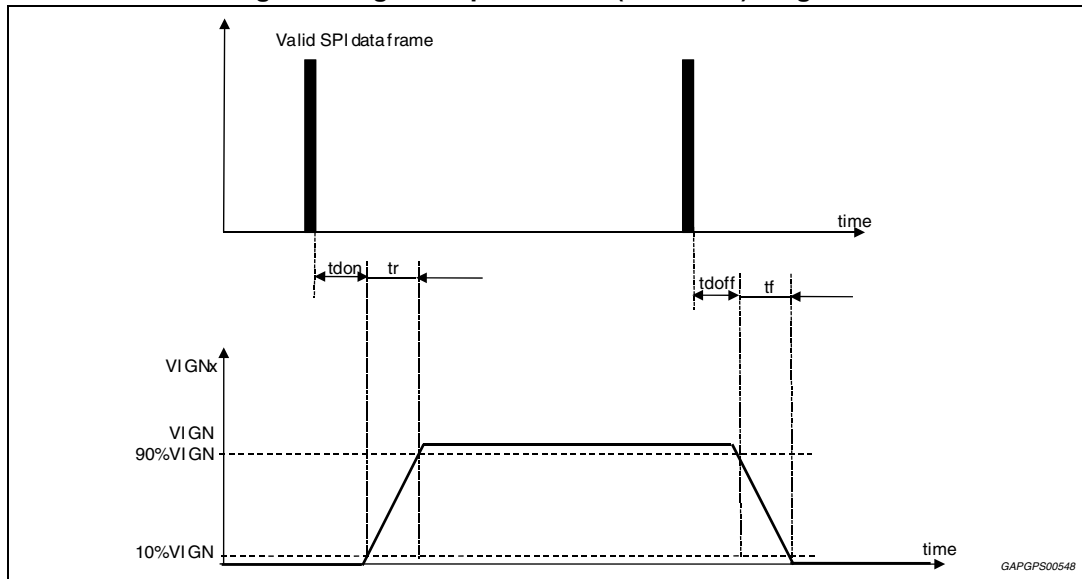
When Reset\_L9779 signal or OUT\_DIS bit is asserted, output IGNx becomes high impedance.

By SPI command it is possible to have the low-side stage always off, in this case there is an external pull down resistor that discharges The IGNx output in Off phase. This Bit is present in CONFIG\_REG2 bit0 and its name is LS\_IGN\_OFF.

**Table 28. Ignition pre-drivers electrical characteristics**

| Pin              | Symbol                   | Parameter   | Test condition                        | Min        | Typ | Max      | Unit |
|------------------|--------------------------|---|---------------------------------------|------------|-----|----------|------|
| IGN1 to 4        | VDD5                     | Supply voltage range                              | Info only                             | 4.9        | -   | 5.1      | V    |
|                  | Vign                     | Output voltage high level                         | I_cont = 15 mA                        | 4.35       | -   |          | V    |
|                  | I <sub>leak_out</sub>    | Leakage current                                   | -                                     | -10        | -   | 10       | μA   |
|                  | I <sub>lim</sub>         | High-side current limitation                      | -                                     | 19         | -   | 33       | mA   |
|                  | I <sub>LS_cont</sub>     | LS path continuous current capability             | Add also the R <sub>DS(on)</sub> Test | -          | -   | 30       | mA   |
|                  | I <sub>LS_RD S on</sub>  | LS RDSON  | -                                     | 3          | -   | 14       | Ω    |
|                  | IOVC                     | High side over current detection                  | -                                     | 7          | -   | 14       | mA   |
|                  | VLVT                     | Output short-circuit to Gnd threshold voltage     | -                                     | 1.6        | 1.8 | 2        | V    |
|                  | Vign_scb                 | SCB detection voltage                             | -                                     | VDD5 +0.1V | -   | VDD5 +2V | -    |
|                  | I <sub>ol</sub>          | OL detection current                              | -                                     | 100        | -   | 850      | μA   |
|                  | T <sub>don</sub>         | Output on delay time                              | Clgn = 10 nF                          | -          | -   | 10       | μs   |
|                  | T <sub>ign_filt</sub>    | OVC/Open load diagnosis filter time, Test by scan | -                                     | 50         | -   | 100      | μs   |
|                  | T <sub>r</sub>           | Output on rise time                               | Clgn = 10 nF                          | -          | -   | 10       | μs   |
|                  | T <sub>doff</sub>        | Output off delay time                             | Clgn = 10 nF                          | -          | -   | 10       | μs   |
|                  | T <sub>f</sub>           | Output off fall time                              | Clgn = 10 nF                          | -          | -   | 10       | μs   |
|                  | R <sub>load</sub>        | Resistive load                                    | For info only                         | 1          | -   | 10       | kΩ   |
| C <sub>out</sub> | Output capacitance loads | For info only                                     | 4                                     | -          | 15  | nF       |      |

Figure 44. Ignition-pre drivers (IGN1 to 4) diagram



### 6.10.2 Ignition pre-driver diagnosis

Each channel locally detects and writes its own fault or no-fault condition (codified on 2 bit according to [Table 27: Fault encoding condition](#)).

The detected faults are:

- IGNx short circuit to battery (SCB)
- IGNx open load (OL)
- IGNx short to GND (SCG)

#### Short to GND

This diagnosis is made in two different ways based on the status of IGN\_DIA\_SGEN.

If IGN\_DIA\_SGEN = 1

When the IGNx is on, if for a time longer than Tign\_filt, the current is bigger than IOVC, the short to GND fault is detected and the IGNx output becomes high impedance, the fault is latched and is reset at every Read Diag operation.

If IGN\_DIA\_SGEN = 0

When the IGNx is on, if for a time longer than Tign\_filt, the voltage of IGNx is lower than VLVT, the short to GND fault is detected and the IGNx output becomes high impedance, the fault is latched and is reset every Read Diag operation.

The high impedance is removed and IGNx is driven by the command:

- after a Read Diag operation
- if command is switched OFF and ON again.

#### Open load

When IGNx is on, if for a time longer than Tign\_filt, the current is below Iol the open-load fault is detected, latched and it is reset at every Read Diag operation. IGNx remains always driven.

### Short circuit to battery

When the load is on, if the voltage of IGNx is bigger than the Vign\_scb threshold for a time longer than Tign\_filt the SCB fault is detected and the output IGNx becomes high impedance.

When the load is off, if the voltage of IGNx is bigger than the Vign\_scb threshold for a time longer than Tign\_filt the SCB fault is detected and the output IGNx becomes high impedance.

The SCB fault has a higher priority with respect to the OL fault.

According to the IGN\_DIA\_MODE bit, two behaviours are possible:

1. Latch mode

The fault is latched and is reset at every Read Diag operation.

The high impedance is removed and IGNx is driven by the command:

- after a Read Diag operation
- if the command is switched OFF and ON again.

2. No latch mode

The fault is not latched and if the voltage of IGNx is lower than the Vign\_scb threshold for a time longer than Tign\_filt the fault state disappears and the high impedance is removed.

## 6.11 Configurable power stages (CPS) (OUTA to OUTD)

### 6.11.1 Configurable power stages functionality description

L9779WD-SPI half bridges with 1 low side N-channel power stage and 1 high side P-channel power stages [OUTA to OUTD] that can be arranged as follows using the CPS\_CONF bit (default H-bridge):

- The low side of each half can be connected in parallel to obtain a low side driver with lower Rdson resistance.

For three reasons outputs are switched in parallel:

- a) to increase current capability (please see electrical characteristic)
- b) to reduce power dissipation (please see electrical characteristic)
- c) to increase clamp energy capability (please see electrical characteristic) The max. clamping energy is probably less than the sum of the corresponding max. clamping energies.

Parallel connection of Low-side power stages is possible as the control bit to turn-on and off the power stages is allocated in the same register. Unlike the H-bridge configuration, no coherency check is done.

When configured for stepper motor driving the motor movement is controlled through bit EN, DIR and PWM input SPI bit (see [Table 29](#)).

In single power stage configuration HS and LS power stages (OUT21...OUT28) can be used as single power stages, and any of them can be connected in parallel to each other (same type).

Stepper is controlled by the logic AND between PWM input pin and PWM SPI bit. Thus to control it by PWM input, SPI PWM bit must be set first, and to do it by SPI PWM bit, PWM input pin must be set first.

If the bit EN=1, the writing of bit PWM from 0 to 1 leads to the next step of the turn on sequence. The writing of bit PWM to 0 left unchanged the MOS of the bridge that is ON. The step is done only if the PWM bit goes from 0 to 1.

The order of the turn-on sequence is defined by the bit DIR.

**Table 29. Configuration of the stepper motor**

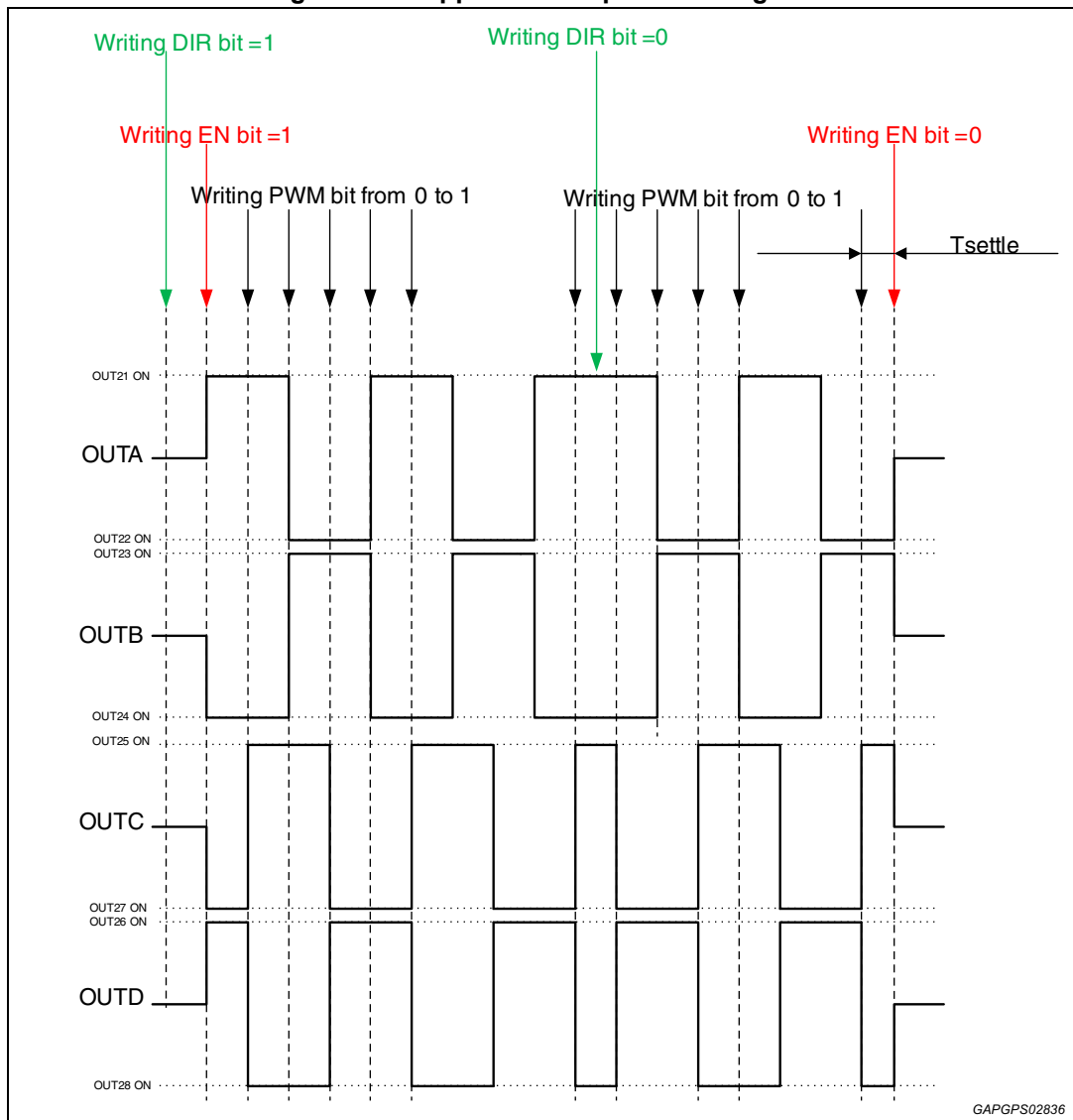
| PWM | EN | DIR | H-bridge 1 Power on | H-bridge 2 Power on |
|-----|----|-----|---------------------|---------------------|
| X   | 0  | X   | None                | None                |
| 1   | 1  | 1   | OUTA_HS, OUTB_LS    | OUTD_HS, OUTC_LS    |
| 1   | 1  | 1   | OUTA_HS, OUTB_LS    | OUTC_HS, OUTD_LS    |
| 1   | 1  | 1   | OUTB_HS, OUTA_LS    | OUTC_HS, OUTD_LS    |
| 1   | 1  | 1   | OUTB_HS, OUTA_LS    | OUTD_HS, OUTC_LS    |
| 1   | 1  | 0   | OUTA_HS, OUTB_LS    | OUTD_HS, OUTC_LS    |
| 1   | 1  | 0   | OUTB_HS, OUTA_LS    | OUTD_HS, OUTC_LS    |
| 1   | 1  | 0   | OUTB_HS, OUTA_LS    | OUTC_HS, OUTD_LS    |
| 1   | 1  | 0   | OUTA_HS, OUTB_LS    | OUTC_HS, OUTD_LS    |

The initial stepper position, after power-on, is the one with OUTA\_HS, OUTB\_LS ON in Hbridge1 and with OUTD\_HS, OUTC\_LS ON in Hbridge2.

If configured as H-bridges the internal logic prohibits that the low-side and the high-side switch of the same half-bridge will be switched on simultaneously.

In the below diagram the stepper motor operation is available.

Figure 45. Stepper motor operation diagram



The writing of DIR bit and PWM bit cannot be done in the same time, at least two consecutive SPI frames are necessary.(if done the stepper will move one step in the old direction).

The writing of EN bit and PWM bit cannot be done in the same time, at least two consecutive SPI frames are necessary. (If done it is supposed that only the EN bit has been received).

Table 30. Half bridge 1

| H-bridge1 | Comment        | Nominal current | Ron max | Switch off current (min.) | Clamping (typ.) |
|-----------|----------------|-----------------|---------|---------------------------|-----------------|
| OUTA      | High-side P-Ch | 0.6 A           | 1.7 Ω   | 1 A                       | N/A             |
|           | Low-side N-Ch  | 0.6 A           | 1.5 Ω   | 1 A                       | 45 V            |

**Table 31. Half bridge 2**

| H-bridge2 | Comment        | Nominal current | Ron max | Switch off current (min.) | Clamping (typ.) |
|-----------|----------------|-----------------|---------|---------------------------|-----------------|
| OUTB      | High-side P-Ch | 0.6 A           | 1.7 Ω   | 1 A                       | N/A             |
|           | Low-side N-Ch  | 0.6 A           | 1.5 Ω   | 1 A                       | 45 V            |

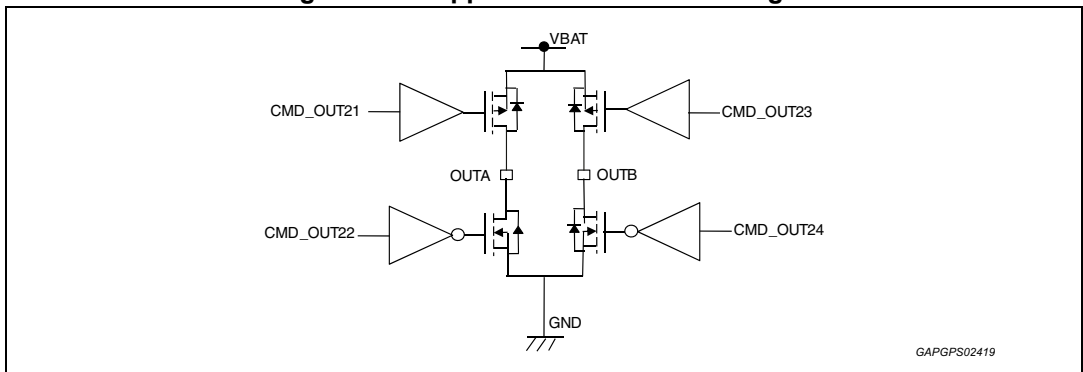
**Table 32. Half bridge 3**

| H-bridge3 | Comment        | Nominal current | Ron max | Switch off current (min.) | Clamping (typ.) |
|-----------|----------------|-----------------|---------|---------------------------|-----------------|
| OUTC      | High-side P-Ch | 0.6 A           | 1.7 Ω   | 1 A                       | N/A             |
|           | Low-side N-Ch  | 0.6 A           | 1.5 Ω   | 1 A                       | 45 V            |

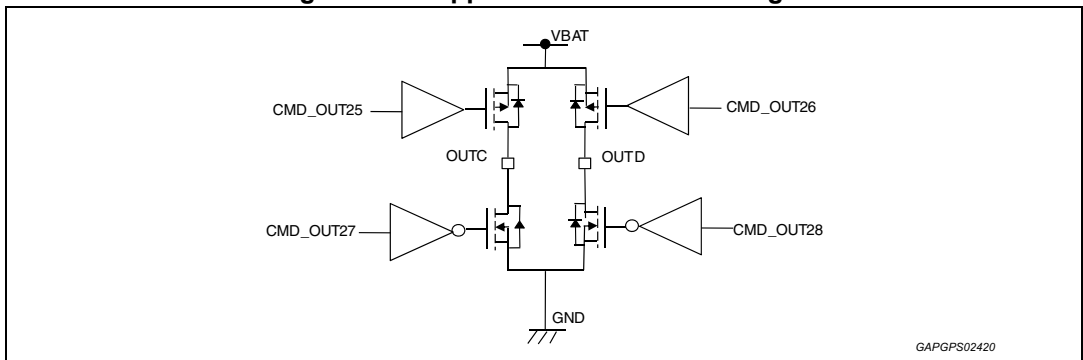
**Table 33. Half bridge 4**

| H-bridge4 | Comment        | Nominal current | Ron max | Switch off current (min.) | Clamping (typ.) |
|-----------|----------------|-----------------|---------|---------------------------|-----------------|
| OUTD      | High-side P-Ch | 0.6 A           | 1.7 Ω   | 1 A                       | N/A             |
|           | Low-side N-Ch  | 0.6 A           | 1.5 Ω   | 1 A                       | 45 V            |

**Figure 46. Stepper motor driver: H-bridge1**



**Figure 47. Stepper motor driver: H-bridge2**



### 6.11.2 Diagnosis of configurable power stages (CPS)

All CPS have fault diagnostic functions:

- Short-circuit to battery voltage: (SCB) can be detected if switches are turned on
- Short-circuit to ground: (SCG) can be detected if switches are turned off
- Open load: (OL) can be detected if switches are turned off
- Over temperature: (OT) will be detected with the general thermal warning(OT2)

Diagnosis is different for configuration as full-bridges or as single power stages. The faults are coded in different way and are stored in diagnostic registers.

In each configuration the registers can be read via SPI. With the beginning of each read cycle the registers are cleared automatically.

In each configuration there is one central diagnostic bit F2 for fault occurrence at any output.

### 6.11.3 Diagnosis of CPS [OUTA to OUTD] when configured as H-bridges

Stepper motor driver OFF diagnosis (output in high impedance state).

In OFF condition Short to GND/Short to VB or Open Load condition is continuously detected through a deglitch filter Tdgc\_off, after Tmask\_step masking time to filter ON/ OFF transition. To avoid false diagnostic due to motor residual movement, the off command (EN bit=0) must be sent Tsettle time after the last valid on command PWM bit written to 1 (one couple of HS and LS switched on). A fault longer than deglitch time is latched.

Off state diagnostic fault can be overwritten by on state fault.

Off state fault does not prevent the stepper from switching on. The latched fault is cleared by reading the diagnosis data registers via SPI - and so resetting the diagnosis registers.

An Off state due to a wrong command sent by SPI interface does not activate the Off diagnosis.

Stepper motor driver ON diagnosis (Output driven by SPI CONTR\_REG bit)

In ON condition when over current fault is detected and validated after digital filtering time Tdgc\_ON, the bridge is turned OFF and the fault is latched. The bridge is turned ON again by SPI command. The latched fault is cleared by reading the diagnosis data registers via SPI and so resetting the diagnosis registers.

Over current fault has higher priority over OFF condition faults.

Each Bridge has dedicated fault diagnosis register H1\_DIAG, H2\_DIAG.

In ON condition if the current in the load current is lower than I\_OPEN\_LOAD for a time longer than Tdgc\_ol\_on, an Open load condition is detected

It could be necessary two steps of the stepper motor operation to detect the real kind of fault, in this case as first diagnosis the fault is "Fault detection running" and with the next PWM command it is possible to understand if the fault is an OPEN LOAD or an OVERCURRENT/SHORT to GND.

The Faults "DETECTION\_RUNNING" & "OPEN LOAD" are latched during the during rise & fall edge of low-side driver command, if the fault disappeared during these phases the fault condition is no latched:

- The FAULT DETECTION RUNNING is no latched, the fault comes back to 0 if the current becomes higher than open load threshold, before the switch off of low-side driver.
- The FAULT OPEN LAOD is no latched, the fault comes back to 0 if the current becomes higher than open load threshold, before the switch off of low-side driver.

A diagnostic read will clear the "fault detection running" flag. Anyway the diagnostic will restart.

**Figure 48. Stepper motor driver "off" diagnosis time diagram**

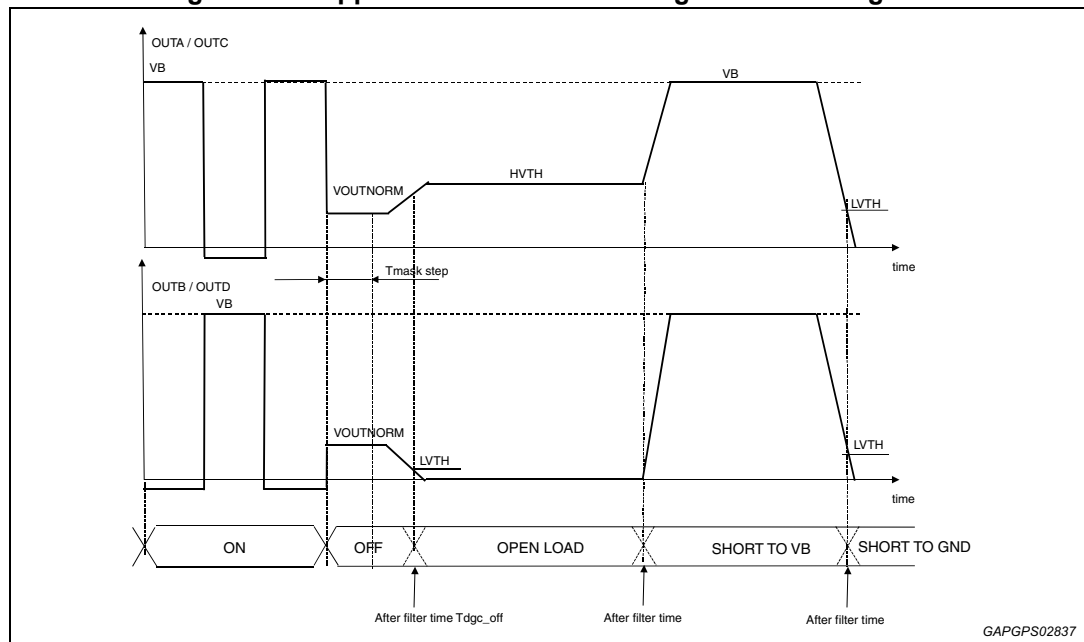
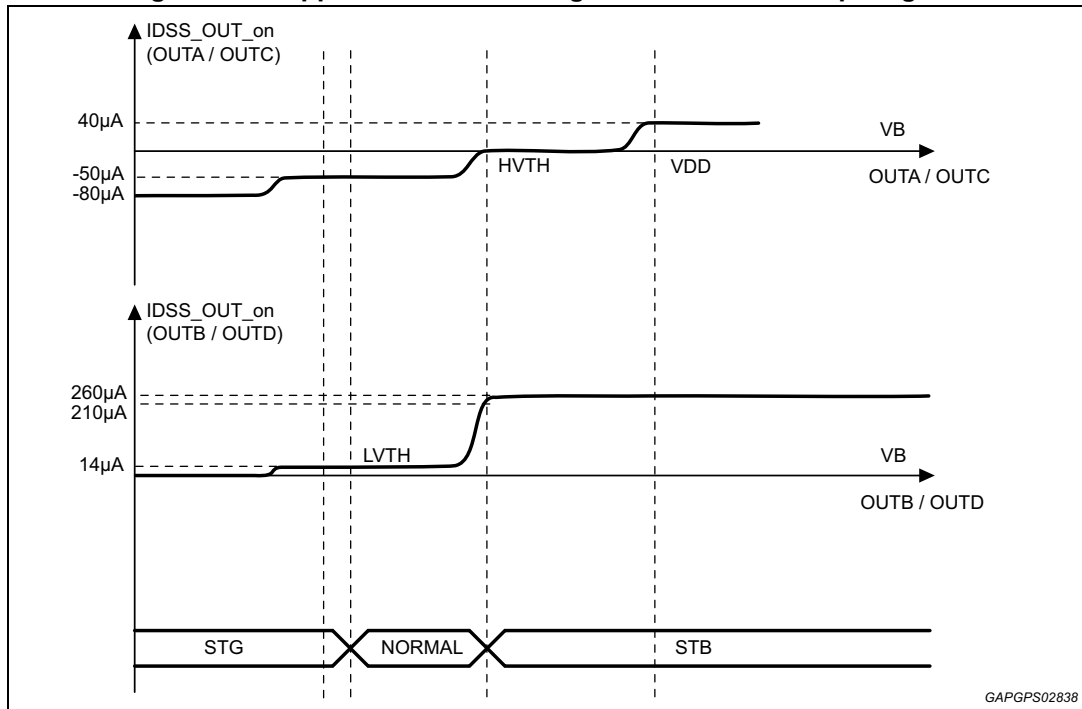




Figure 49. Stepper motor driver diagnosis I-V relationship diagram



Note: this wave shows the I/V relationship of pin current and pin voltage when  $OUTA(OUTC)$  short to  $OUTB(OUTD)$  and force the pin voltage from 0 V to  $V_B$  in typical condition. For example, when pin voltage of  $OUTA = OUTB = 1.5$  V, the pull up/down current is about -50  $\mu A$  for  $OUTA$  and about 14  $\mu A$  for  $OUTB$ . When pin voltage of  $OUTA = OUTB = 5$  V, the pull up/down current is about 40  $\mu A$  for  $OUTA$  and about 220  $\mu A$  for  $OUTB$ .

Figure 50. Open load detection during "on" phase

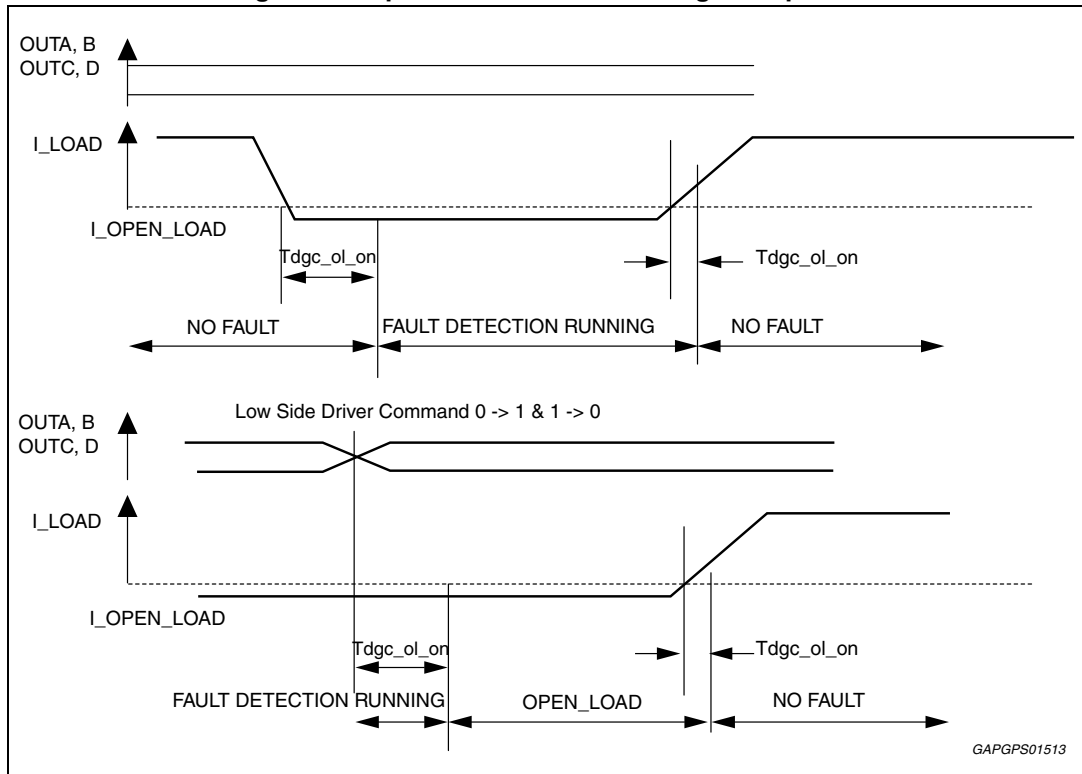


Figure 51. Open load detection during "on" phase

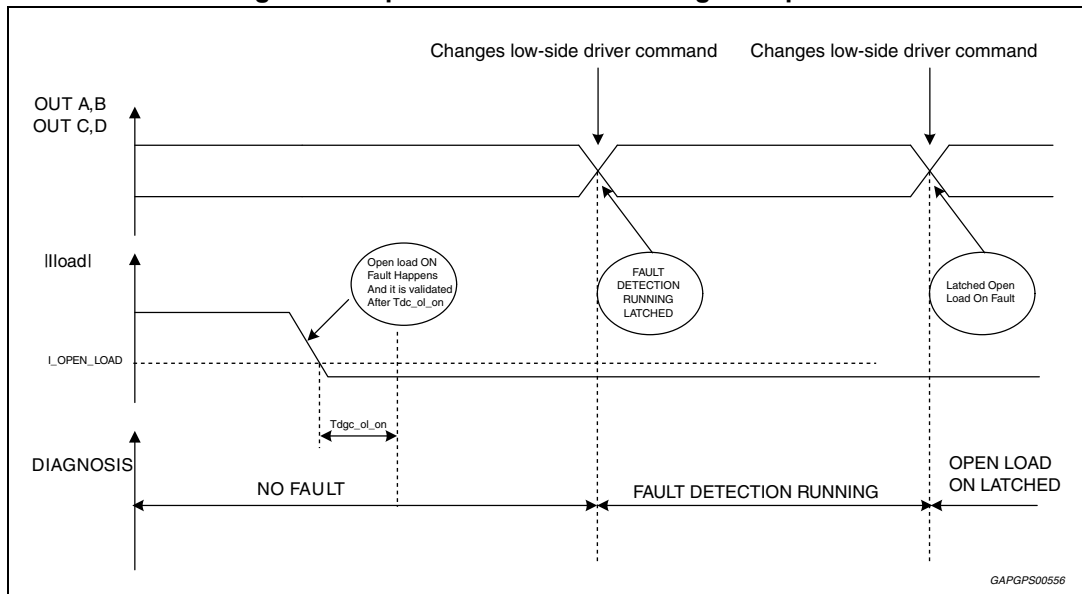


Figure 52. Short to GND detection during “on” phase

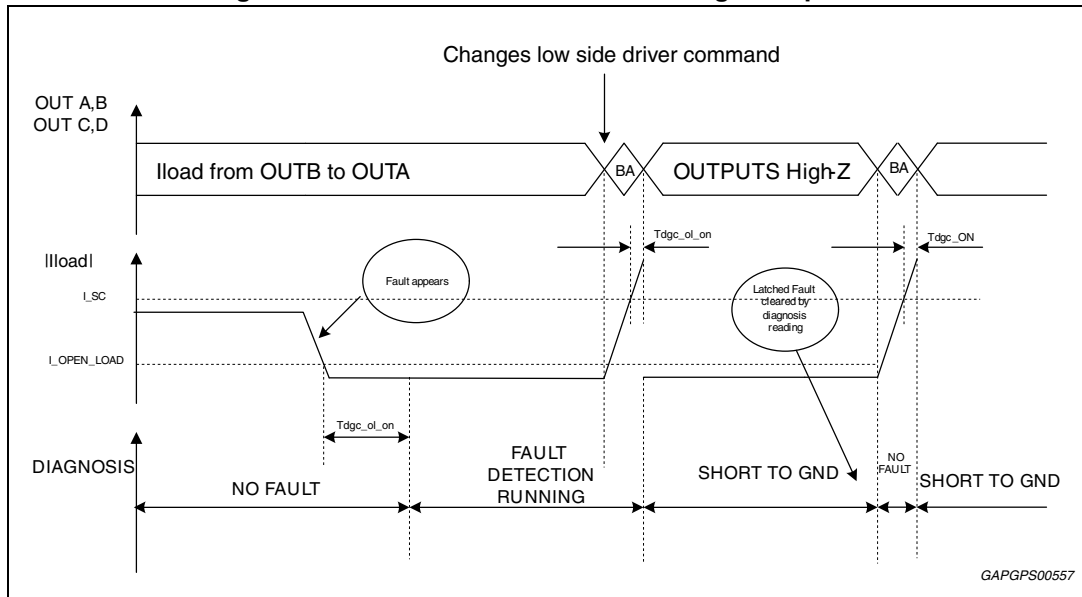


Table 34. Stepper configuration electrical characteristics

| Pin        | Symbol                       | Parameter  | Test condition   | Min                   | Typ | Max                   | Unit       |
|------------|------------------------------|--|--|-----------------------|-----|-----------------------|------------|
| OUT A to D | $V_{Outnorm}$                | OUT(21,22),<br>OUT(23,24),<br>OUT(25,27),<br>OUT(26,28) output voltage | OUT(21,22) short to<br>OUT(23,24);<br>OUT(25,27) short to<br>OUT(26,28); | 2.3                   | -   | 2.7                   | V          |
|            | $H_{VTH}$                    | Diagnostic high threshold  | Driver in OFF condition  | $V_{Outnorm} + 120mV$ | -   | 3                     | V          |
|            | $L_{VTH}$                    | Diagnostic low threshold   | Driver in OFF condition  | 1.9                   | -   | $V_{Outnorm} - 200mV$ | V          |
|            | $I_{ovc}$                    | Over current threshold   | -  | 1                     | -   | 2.1                   | A          |
|            | $I_{OPEN\_LOAD}$             | Output open load threshold current                                     | -  | 10                    | -   | 90                    | mA         |
|            | $I_{OUT\_PD\_A+B}$<br>or C+D | Output diagnostic pull down current OFF STATE                          | $V_{pin} = 5 V$  | 200                   | -   | 350                   | $\mu A$    |
|            | $I_{OUT\_PU\_A+B}$<br>or C+D | Output diagnostic pull up current OFF STATE                            | $V_{pin} = 1.5 V$  | 50                    | -   | 150                   | $\mu A$    |
|            | $R_{openl}$                  | Open load resistor threshold   | Application note   | 150                   | -   | -                     | k $\Omega$ |
|            | $Tdgc\_ON$                   | Degitch filter time in ON condition                                    | Test by scan   | -25%                  | 10  | +25%                  | $\mu s$    |
|            | $Tdgc\_OFF$                  | -  | Test by scan   | -25%                  | 125 | +25%                  | $\mu s$    |
|            | $Tdgc\_ol\_on$               | -  | Test by scan   | -25%                  | 20  | +25%                  | $\mu s$    |

Table 34. Stepper configuration electrical characteristics (continued)

| Pin        | Symbol     | Parameter           | Test condition                     | Min  | Typ | Max  | Unit |
|------------|------------|---------------------|------------------------------------|------|-----|------|------|
| OUT21...28 | Tmask_step | -                   | Test by scan                       | -25% | 1   | +25% | ms   |
|            | Tsettle    | -                   | For information only;<br>No tested | 100  | -   | -    | ms   |
|            | T_PWM      | Operating frequency | For information only;<br>No tested | 50   | -   | -    | μs   |

#### 6.11.4 Diagnosis of CPS OUTA, B, C, D when configured as single low side power stages

For the low side the diagnosis is the same as LSd (see [Section 6.9](#)).

Each channel locally detects and writes its own fault or no-fault condition (codified on 2 bit according to [Table 27: Fault encoding condition](#)).

- Short circuit to battery or overcurrent for all the outputs during ON condition.
- Open load or short to GND during OFF condition.

The faults are latched and reset at every Read Diag operation.

In OFF condition the first fault detected is latched and can be overwritten only by the ON condition fault.

### Electrical and diagnosis characteristics of OUTA, B, C, D when configured as single power stages

Same parameter and diagnosis function as LSd.

**Table 35. Electrical and diagnosis characteristics of OUTA, B, C, D when configured as single power stages**

| Pin  | Symbol                                  | Parameter   | Test condition   | Min | Typ  | Max | Unit             |
|--|---|---|--|-----|------|-----|------------------|
| OUTA,<br>OUTB,<br>OUTC,<br>OUTD  | $R_{DS-on\ LSd}$                        | Drain source resistance   | $I_{load} = 0.6\text{ A}$  | -   | -    | 1.5 | $\Omega$         |
|  | $I_{OUT\ lk}$                           | Output leakage current  | $V_{pin} = 13.5\text{ V}$  | -   | -    | 10  | $\mu\text{A}$    |
|  | $V_{S/R}$                               | Voltage S/R On/off  | $R = 21\ \Omega$ , $C = 10\text{nF}$<br>From 80% to 30% of $V_{OUT}$                     | 2   | -    | 6   | V/us             |
|  | $V_{S/R\ GateKill}$                     | Fast VR/S off when an OVC fault happens                                     | Load: $8\ \Omega$ , $10\text{nF}$ - from 80% to 30% of $V_{OUT}$                         | 5   | -    | 30  | V/ $\mu\text{s}$ |
|  | $T_{Turn-On\_LSd}$                      | Turn-on delay time  | From command to 80% $V_{OUT}$ Load: $21\ \Omega$ , $10\text{nF}$                         | -   | -    | 6   | $\mu\text{s}$    |
|  | $T_{Turn-Off\_LSd}$                     | Turn-off delay time   | From command to 30% $V_{OUT}$ Load: $21\ \Omega$ , $10\text{nF}$                         | -   | -    | 6   | $\mu\text{s}$    |
|  | $V_{cl}$                                | Output clamping voltage   | $I_{load} = 0.6\text{ A}$  | 46  | 48   | 50  | V                |
|  | $PW_{clampSP}$                          | Clamp single pulse ATE test   | $I_{load} = 0.6\text{ A}$ ; single pulse   | -   | -    | 15  | mJ               |
|  | $PW_{clampRP}$                          | Clamp repetitive pulses<br>Freq = 1 Hz<br>(to be verified) Reliability Test | $T_c \leq 30\text{ }^\circ\text{C}$ ;<br>$I_{OUT\_n} \leq 0.45\text{ A}$<br>1 Mio cycles | -   | -    | 6.5 | mJ               |
|  |   |   | $T_c \leq 80\text{ }^\circ\text{C}$ ;<br>$I_{OUT\_n} \leq 0.3\text{ A}$<br>25 Mio cycle  | -   | -    | 6.5 |                  |
| $T_c \leq 100\text{ }^\circ\text{C}$ ;<br>$I_{OUT\_n} \leq 0.3\text{ A}$<br>20 Mio cycle |   |   | -  | -   | 6.5  |     |                  |
| $T_c \leq 130\text{ }^\circ\text{C}$ ;<br>$I_{OUT\_n} \leq 0.3\text{ A}$<br>5 Mio cycle  |   |   | -  | -   | 5.5  |     |                  |
| Reverse voltage  | Body diode reverse current voltage drop | $I = -0.6\text{ A}$   | -0.5   | -1  | -1.1 | V   |                  |

**Electrical characteristics of OUTA, B, C, D when configured as single power stages connected in parallel**

When the low side drivers are connected in parallel (in pair) to obtain a low side driver with a lower resistance, OUTA with OUTB and OUTC with OUTD, for example the following parameters are valid:

**Table 36. Electrical characteristics of OUTA, B, C, D when configured as single power stages connected in parallel**

| Pin                             | Symbol                 | Parameter  | Test condition   | Min  | Typ | Max  | Unit |
|---------------------------------|------------------------|--|--|--|-----|------|------|
| OUTA,<br>OUTB,<br>OUTC,<br>OUTD | I <sub>max</sub>       | Output current   | Not tested   | -  | 1.2 | -    | A    |
|                                 | R <sub>DS-on LSd</sub> | Drain source resistance                                    | I <sub>load</sub> = 1.2 A  | -  | -   | 0.75 | Ω    |
|                                 | I <sub>OUT_ik</sub>    | Output leakage current                                     | (1)  | -  | -   | 10   | μA   |
|                                 | V <sub>S/R</sub>       | Voltage S/R on/off   |  | 2  | -   | 6    | -    |
|                                 | T <sub>Turn-on</sub>   | Turn-on delay time   |  | -  | -   | 6    | μs   |
|                                 | T <sub>Turn-off</sub>  | Turn-off delay time  |  | -  | -   | 6    | μs   |
|                                 | I <sub>OVc</sub>       | Over current threshold                                     |  | 2  | -   | 4.2  | A    |
|                                 | PW <sub>clampSP</sub>  | Clamp single pulse   |  | I <sub>load</sub> = 1 A; single pulse <sup>(1)</sup> | -   | -    | 25   |
|                                 | PW <sub>clampRP</sub>  | Clamp repetitive pulses                                    | Reliability note:<br>I <sub>load</sub> = 0.6 A<br>Freq = 10 Hz;<br>36 Mpulse (1000h) | -  | -   | 12   | mJ   |
|                                 | I <sub>OUT_PD</sub>    | Output diagnostic pull down current off state              | V <sub>pin</sub> = 5 V   | 50   | -   | 110  | μA   |
|                                 | I <sub>OUT_PU</sub>    | Output diagnostic pull up current off state                | (1)  | -210   | -   | -108 | μA   |
|                                 | ΔV <sub>clamp</sub>    | Delta clamping voltage between low side to be parallelized |  | -250   | -   | +250 | mV   |

1. Not to be tested, already covered by single low side measure and guaranteed by design.

**(CPS) CONFIG\_REG10**

**Table 37. CPS table single mode parallelism**

| Register bit         | 7 | 3 | 2 | 1 | 0 | The table configuration will be active if confi_reg7-bit4 is configured at Zero (Default at 1)<br>If not specified Output Drivers are set as single (not in parallel with any other)<br>Over Current mask time increased to 8 μs | Enable by    | Diagnostic   |
|----------------------|---|---|---|---|---|--|--------------|--------------|
| 4Low                 | 0 | 1 | 0 | 0 | 0 | OUT22 and OUT24 and OUT27 and OUT28 Low side Parallel  | OUT24        | OUT22        |
| 2 LSSingle + 2 LSPar | 0 | 0 | 0 | 1 | 0 | OT27 and OUT28 single + OUT22 and OUT24 parallel   | OUT24        | OUT22        |
| 2 LSPar + 2 LSPar    | 0 | 0 | 1 | 0 | 0 | OT27 and OUT28 single + OUT22 and OUT24 parallel   | OUT24, OUT27 | OUT22, OUT27 |
| 3 LSPar              | 1 | 1 | 1 | 0 | 0 | OUT24 and OUT27 and OUT28 parallel   | OUT24        | OUT24        |

There are three configurations of CONFIG\_REG10 register which allow enabling HS drivers. These configurations shall be used by taking care of not switching on HS and LS drivers simultaneously on the same OUTx path. Note that for Parallel HS configurations, HS diagnostic current is doubled.

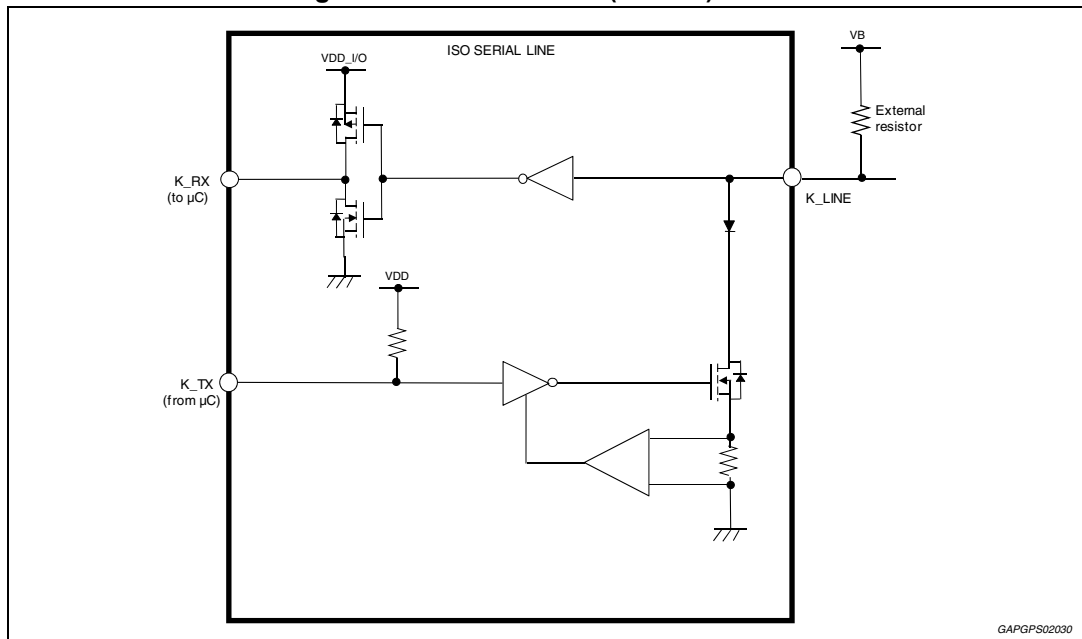
**Table 38. Three configurations of CONFIG\_REG10 register**

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | These configurations allow enabling HS drivers and LS drivers in CPS mode | Enable by    | Diagnostic |
|---|---|---|---|---|---|---|---|---|--------------|------------|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Single drivers can be enabled by sending related command                  | CMD_OUTx     | OUTx       |
| 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | OUT25 and OUT26 parallel + OUT22 and OUT24 parallel + all others Single   | OUT24,OUT25  | OUT22      |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | OUT21 and OUT23 parallel + OUT27 and OUT28 parallel + all others Single   | OUT23, OUT27 | OUT27      |

*Note:* When those four single Lside and four single Hside are configured as parallel configuration, for example 2 single Lside stage to 1 Lside stage or 4 single Lside stage to 1 Lside stage, the Rdsn could be 1/2 or 1/4 as one single stage, the over current threshold could be roughly double or 4 times as single stage, but the over current detected filter time will be increased to 2 times as single stage from 4 μs typical to 8 μs typical by L9779WD-SPI itself, because each single stage will switch on its own overcurrent threshold no matter the configuration for off stage diagnostic, all thresholds will be kept as single stage whatever the configuration of those 4 Lside/Hside.

## 6.12 ISO serial line (K-LINE)

Figure 53. ISO serial line (K-LINE) circuit



### 6.12.1 ISO serial line (K-LINE) functionality description

The ISO serial line is an interface containing one bidirectional line for communication between the μP and an external diagnosis tester or antitheft device. In case of ground loss the outputs K\_LINE get in high impedance state and can withstand a negative voltage up to -18 V. Short circuit to Vb protection is provided: if the K\_LINE pin is shorted to battery the output is switched off after a delay of  $t_{filter\_K\_LINE}$  and it is necessary an input change to turn on it again.

The negative transition at K\_LINE pin can be driven with slew-rate limitation for optimizing the EMI behavior. This slew-rate limitation must be enabled via the ISO\_SRC bit.

The K\_TX signal is ignored (K\_LINE pin to high level) until the RST pin is asserted.

KLINE can work up to 250kHz input frequency in typical application condition.



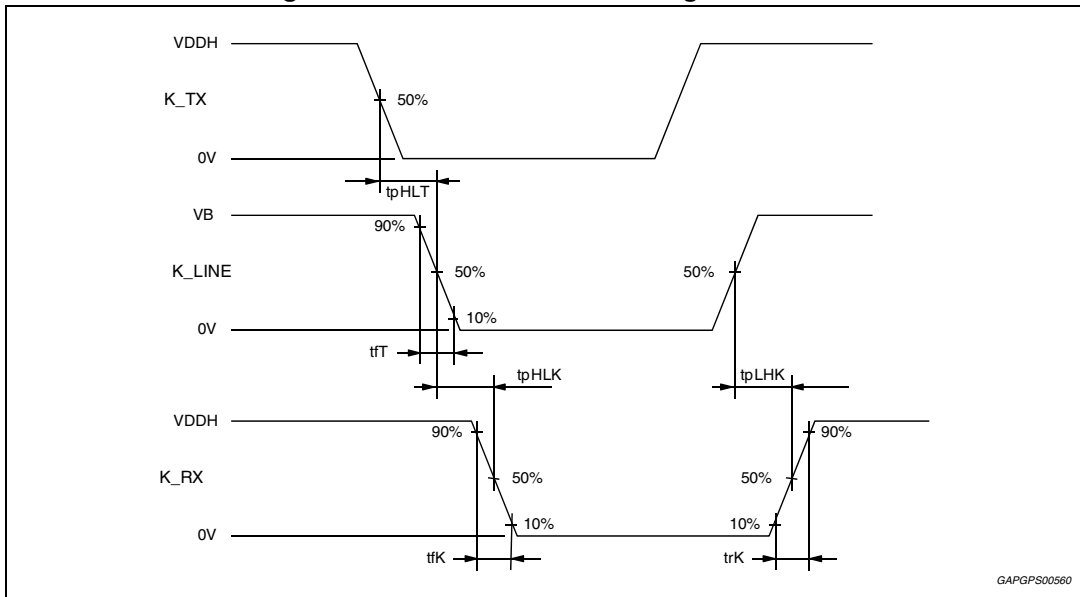
Table 39. ISO serial line (K-LINE) functionality electrical characteristic

| Pin             | Symbol                     | Parameter                           | Test condition   | Min                         | Typ | Max      | Unit |
|-----------------|----------------------------|-------------------------------------|--|-----------------------------|-----|----------|------|
| K_TX            | V <sub>KTXL</sub>          | K_TX input low voltage              | -  | -0.3                        | -   | 1.1      | V    |
|                 | V <sub>KTXH</sub>          | K_TX input high voltage             | -  | 2.3                         | -   | VDD +0.3 | V    |
|                 | R <sub>TX_KPU</sub>        | TX_KLINE pull-up resistor           | -  | 50                          | -   | 250      | kΩ   |
|                 | I <sub>TXsink</sub>        | Transmitter input sink current      | K_LINE = 0, K_TX = High  | -                           | -   | 5        | μA   |
| K_LINE          | V <sub>KOUTL</sub>         | Transmitter output low voltage      | I <sub>sink_K_LINE</sub> = 35 mA, K_TX = Low                                 | -1                          | -   | 1.5      | V    |
|                 | I <sub>KOS</sub>           | Transmitter short circuit current   | K_LINE = VB, K_TX = Low  | 60                          | -   | 165      | mA   |
|                 | T <sub>filter_K_LINE</sub> | Overcurrent filter time             | Test by SCAN   | 7                           | 10  | 13       | μs   |
|                 | I <sub>KREV</sub>          | Reverse battery or GND loss current | Key_on = VB = 0 V<br>K_LINE = -18 V  | -                           | -   | 10       | mA   |
|                 |                            | Under voltage current               | Key_on = High,<br>K_TX = Low, VB = 13.5 V,<br>K_LINE = -1V                   | -                           | -   | 1        | mA   |
|                 | V <sub>KH</sub>            | Receiver input hysteresis           | -  | 0.08*VB                     | -   | 0.3*VB   | V    |
|                 | V <sub>KINH</sub>          | Receiver input high voltage         | -  | 0.7* VB                     | -   | VB       | V    |
|                 | V <sub>KINL</sub>          | Receiver input low voltage          | -  | -1                          | -   | 0.35*VB  | V    |
|                 | V <sub>K_SR</sub>          | K_line voltage slew - rate          | From off to on:<br>VB = 13.5 V, R <sub>ext</sub> = 510 Ω<br>C = 10 nF to GND | 5.3                         | -   | 8.8      | V/μs |
|                 |                            |                                     | From on to off   | Depends on external RC load |     | -        |      |
| T <sub>FT</sub> | Transmitter fall time      | CK_LINE = 10 nF,<br>RK_LINE = 510 Ω | -  | -                           | 10  | μs       |      |
| K_RX            | V <sub>KRXL</sub>          | K_RX output low voltage             | VDD_IO = 5 V or 3.3 V<br>I <sub>sink</sub> = 2 mA                            | -                           | -   | 0.5      | V    |
|                 | V <sub>KRXH</sub>          | K_RX output high voltage            | VDD_IO = 5 V or 3.3 V<br>I <sub>source</sub> = 2 mA                          | VDD_IO -0.5                 | -   | -        | V    |
|                 | T <sub>rK</sub>            | K_RX rise time                      | from 10% to 90%<br>With 20 pF capacitive load                                | -                           | -   | 2        | μs   |
|                 | T <sub>fK</sub>            | K_RX fall time                      | from 90% to 10%<br>20 pF capacitive load                                     | -                           | -   | 2        | μs   |
| K_TX, K_LINE    | Tp_HLT                     | Transmitter turn-on delay time      | CK_LINE = 10 nF,<br>RK_LINE = 510 Ω  | -                           | -   | 5        | μs   |

**Table 39. ISO serial line (K-LINE) functionality electrical characteristic (continued)**

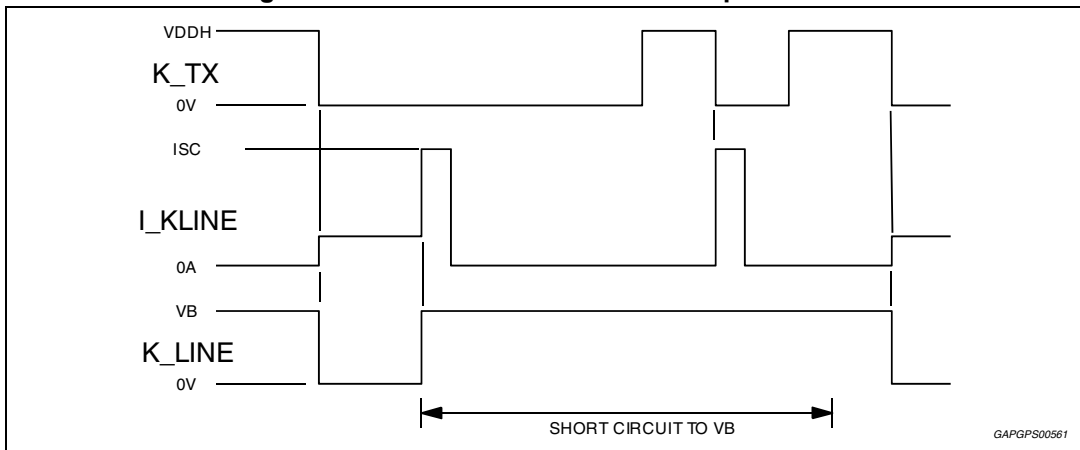
| Pin             | Symbol | Parameter                | Test condition            | Min | Typ | Max | Unit |
|-----------------|--------|--------------------------|---------------------------|-----|-----|-----|------|
| K_LINE,<br>K_RX | TpHLK  | K_RX turn-on delay time  | C <sub>load</sub> = 20 pF | -   | -   | 4   | µs   |
|                 | TpLHK  | K_RX turn-off delay time | C <sub>load</sub> = 20 pF | -   | -   | 4   | µs   |

**Figure 54. ISO serial line switching waveform**



GAPGPS00560

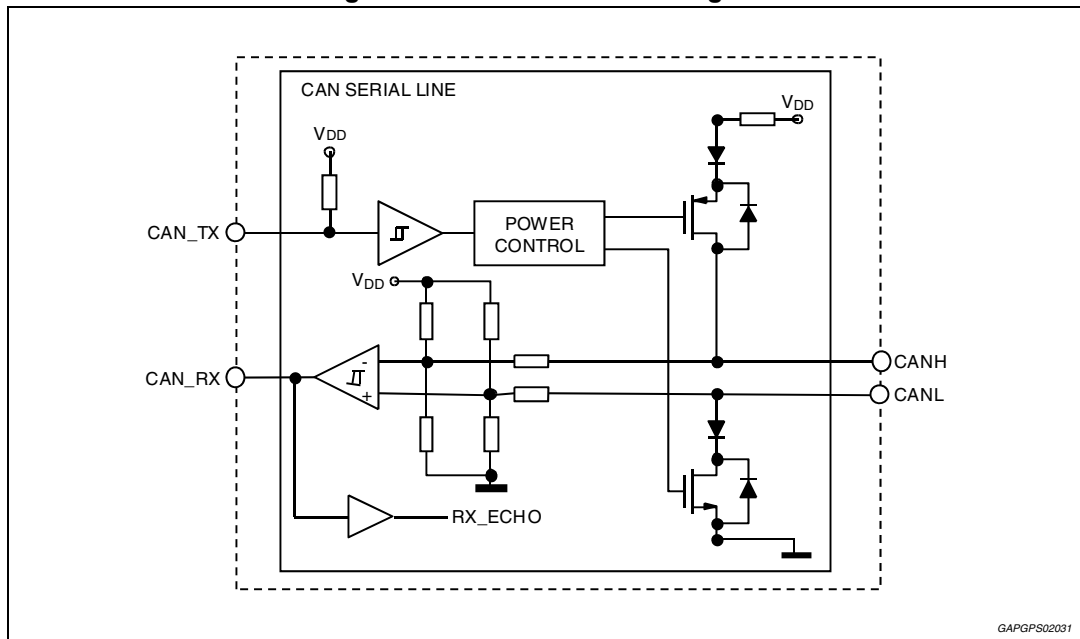
**Figure 55. ISO serial line: short circuit protection**



GAPGPS00561

## 6.13 CAN transceiver

Figure 56. CAN transceiver diagram



### 6.13.1 CAN transceiver functionality description

The CAN bus transceiver allows the connection with a microcontroller through a high speed CAN bus with transmission rates up to 1Mbit/s. The transceiver has one logic input pin (CAN\_TX), one logic output pin (CAN\_RX) and two input/output pins for the electrical connections to the two bus wires (CANH and CANL). The microcontroller sends data to the CAN\_TX pin and it receives data from the CAN\_RX pin.

In case of power loss (VB pin disconnected) or ground loss (GND pins disconnected), the transceiver doesn't disturb the communication of the remaining transceivers connected to the bus. If CANL is shorted to ground, the transceiver is able to operate with reduced EMI/RFI performances.

TX or RX=0 means Dominant state of CANH and CANL; TX or RX=1 means Recessive state compliant to ISO11898-2.

- Speed communication up to 1Mbit/s
- Function range from +40 V to -18 V DC at CAN pins
- GND disconnection fail safe at module level
- GND shift operation at system level
- ESD: Immunity against automotive transients per ISO7637 specification
- Matched output slopes and propagation delay.

The CAN\_TX signal is ignored (CAN to recessive state) until the RST pin is asserted.

### CAN error handling

The L9779WD-SPI provides the following 4 error handling features that are realized in different stand alone CAN transceivers / micro controllers to switch the application back to normal operation mode.

If one of the below fault happens the status bit CAN\_ERROR is set.

The error handling features can be disabled through the CAN\_ERR\_DIS bit.

1. Dominant CAN\_TX time out  
 If CAN\_TX is in dominant state (low) for  $t > t_{dom(TxD)}$  the transmitter will be disabled, status bit will be latched and can be read and cleared by SPI. The transmitter remains disabled until the status register is cleared.
2. CAN permanent recessive  
 If CAN\_TX changes to dominant (low) state but CAN bus (CAN\_RX pin) does not follow for 4 times, the transmitter will be disabled, status bit will be latched and can be read and cleared by SPI. The transmitter remains disabled until the status register is cleared.
3. CAN permanent dominant  
 If the CAN bus state is dominant (low) for  $t > t_{CAN}$  a permanent dominant status will be detected. The status bit will be latched and can be read and cleared by SPI. The transmitter will not be disabled.
4. CAN\_RX permanent recessive  
 If CAN\_RX 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 RX\_ECHO does not follow CAN\_TX for 4 times the transmitter will be disabled. The status bit will be latched and can be read and optionally cleared by SPI. The transmitter remains disabled until the status register is cleared.

### CAN transceiver electrical characteristics

Table 40. CAN transceiver electrical characteristics

| Pin    | Symbol                  | Description                                      | Test conditions                          | Min         | Typ | Max      | Unit |
|--------|-------------------------|--|--|-------------|-----|----------|------|
| CAN_TX | V <sub>TX_CANLOW</sub>  | Input voltage dominant level                     | Active mode                              | -0.3        | -   | 1.1      | V    |
|        | V <sub>TX_CANHIGH</sub> | Input voltage recessive level                    | Active mode                              | 2.3         | -   | VDD +0.3 | V    |
|        | V <sub>TX_CANHYS</sub>  | V <sub>TX_CANHIGH</sub> - V <sub>TX_CANLOW</sub> | Active mode                              | 0.25        | 0.5 | -        | V    |
|        | R <sub>TX_CANPU</sub>   | CAN_TX pull up resistor                          | Active Mode                              | 50          | -   | 250      | kΩ   |
| CAN_RX | V <sub>RX_CANLOW</sub>  | Output voltage dominant level                    | Active mode, VDD_IO = 5 V or 3.3 V, 2 mA | -           | -   | 0.5      | V    |
|        | V <sub>RX_CANHIGH</sub> | Output voltage recessive level                   |  | VDD_IO -0.5 | -   | -        | V    |

Table 40. CAN transceiver electrical characteristics (continued)

| Pin            | Symbol  | Description   | Test conditions  | Min                  | Typ          | Max                  | Unit          |
|----------------|---|---|--|----------------------|--------------|----------------------|---------------|
| CAN_H<br>CAN_L | $V_{CANHdom}$   | CANH voltage level in dominant state  | Active mode;<br>$V_{TXCAN} = V_{TXCANLOW}$ ;<br>$R_L = 60 \Omega$            | 2.75                 | -            | 4.5                  | V             |
|                | $V_{CANLdom}$   | CANL voltage level in dominant state  |  | 0.5                  | -            | 2.25                 | V             |
|                | $V_{DIFF,domOUT}$   | Differential output voltage in dominant state: $V_{CANHdom} - V_{CANLdom}$  |  | 1.5                  | -            | 3                    | V             |
|                | $V_{CM}$  | Driver symmetry:<br>$V_{CANHdom} + V_{CANLdom}$                             | $R_L = 60 \Omega$ ; $C_{SPLIT} = 4.7 \text{ nF}$ ;                           | 0.9*<br>$V_{CANSUP}$ | $V_{CANSUP}$ | 1.1*<br>$V_{CANSUP}$ | V             |
|                | $V_{CANHrec}$   | CANH voltage level in recessive state                                       | $V_{TX\_CAN} = V_{TX\_CANHIGH}$ ;<br>No load                                 | 2                    | 2.5          | 3                    | V             |
|                | $V_{CANLrec}$   | CANL voltage level in recessive state                                       |  | 2                    | 2.5          | 3                    | V             |
|                | $V_{DIFF,recOUT}$   | Differential output voltage in recessive state: $V_{CANHrec} - V_{CANLrec}$ |  | -50                  | -            | 50                   | mV            |
|                | $V_{CANHL,CM}$  | Common mode bus voltage   | Application info:<br>Measured with respect to the ground of each CAN node    | -12                  | -            | +12                  | V             |
|                | $I_{OCANH,dom}$   | CANH output current in dominant state                                       | Active mode;<br>$V_{TX\_CAN} = V_{TX\_CANLOW}$ ;<br>$V_{CANH} = 0 \text{ V}$ | -100                 | -75          | -45                  | mA            |
|                | $I_{OCANL,dom}$   | CANL output current in dominant state                                       | Active mode;<br>$V_{TX\_CAN} = V_{TX\_CANLOW}$ ;<br>$V_{CANL} = 5 \text{ V}$ | 45                   | 75           | 100                  | mA            |
|                | $I_{Leakage}$   | Input leakage current   | Unpowered device;<br>$V_{BUS} = 5 \text{ V}$                                 | 0                    | -            | 250                  | $\mu\text{A}$ |
|                | $R_{in}$  | Internal resistance   | Active mode<br>$V_{TX\_CAN} = V_{TX\_CANHIGH}$ ;<br>No load                  | 25                   | -            | 45                   | k $\Omega$    |
|                | $R_{in,diff}$   | Differential internal resistance  | Active mode & STBY mode;<br>$V_{TX\_CAN} = V_{TX\_CANHIGH}$ ;<br>No load     | 50                   | -            | 85                   | k $\Omega$    |
|                | $C_{in}$  | Internal capacitance  | Guaranteed by design   | -                    | 20           | -                    | pF            |
|                | $C_{in,diff}$   | Differential internal capacitance   | Guaranteed by design   | -                    | 10           | -                    | pF            |
| $V_{THdom}$    | Differential receiver threshold voltage recessive to dominant state | Active mode   | -  | -                    | 0.9          | V                    |               |

**Table 40. CAN transceiver electrical characteristics (continued)**

| Pin            | Symbol       | Description   | Test conditions | Min | Typ | Max | Unit       |
|----------------|--------------|---|-----------------|-----|-----|-----|------------|
| CAN_H<br>CAN_L | $V_{THrec}$  | Differential receiver threshold voltage dominant to recessive state | Active mode     | 0.5 | -   | -   | V          |
|                | $SR_H$       | CANH slew rate between 10% and 90%                                  | -               | 5   | -   | 35  | V/ $\mu$ s |
|                | $SR_L$       | CANL slew rate between 10% and 90%                                  | -               | 5   | -   | 35  | V/ $\mu$ s |
|                | DIFF_SR      | Slew rate difference between CANH and CANL                          | -               | -   | -   | 60  | %          |
|                | $SR_{VDIFF}$ | Slew rate of $V_{diff} = V_{CANH} - V_{CANL}$                       | -               | 12  | -   | 100 | V/ $\mu$ s |
|                | $V_{THhys}$  | $V_{THdom} - V_{THrec}$ hysteresis                                  | -               | 25  | -   | 50  | mV         |

**Table 41. CAN transceiver timing characteristics**

| Symbol             | Description   | Test conditions  | Min | Typ | Max | Unit    |
|--------------------|---|--|-----|-----|-----|---------|
| $t_{TXpd,hl}$      | Propagation delay TX_CAN to RX_CAN (High to Low)<br>Guaranteed by design. | Active mode; 50% $V_{TX\_CAN}$ to 50% $V_{RX\_CAN}$ ; $C_L = 100$ pF; $C_{RX\_CAN} = 15$ pF; $R_L = 60$ $\Omega$ ; | 0   | -   | 255 | ns      |
|                    |   | $C_{RX\_CAN} = 100$ pF<br>@ $T_{room}$ and $T_{cold}$  | -   | -   | 265 | ns      |
|                    |   | $C_{RX\_CAN} = 100$ pF<br>@ $T_{hot}$  | -   | -   | 275 | ns      |
| $t_{TXpd,lh}$      | Propagation delay TX_CAN to RX_CAN (Low to High)<br>Guaranteed by design. | Active mode; 50% $V_{TX\_CAN}$ to 50% $V_{RX\_CAN}$ ; $C_L = 100$ pF; $C_{RX\_CAN} = 15$ pF; $R_L = 60$ $\Omega$ ; | 0   | -   | 255 | ns      |
|                    |   | $C_{RX\_CAN} = 100$ pF<br>@ $T_{room}$ and $T_{cold}$  | -   | -   | 265 | ns      |
|                    |   | $C_{RX\_CAN} = 100$ pF<br>@ $T_{hot}$  | -   | -   | 275 | ns      |
| $t_{dom(TX\_CAN)}$ | TX_CAN dominant time-out  | Tested by scan   | 525 | 700 | 875 | $\mu$ s |
| $t_{CAN}$          | CAN permanent dominant time-out   | Tested by scan   | -   | 700 | -   | $\mu$ s |

Figure 57. CAN transceiver switching waveforms

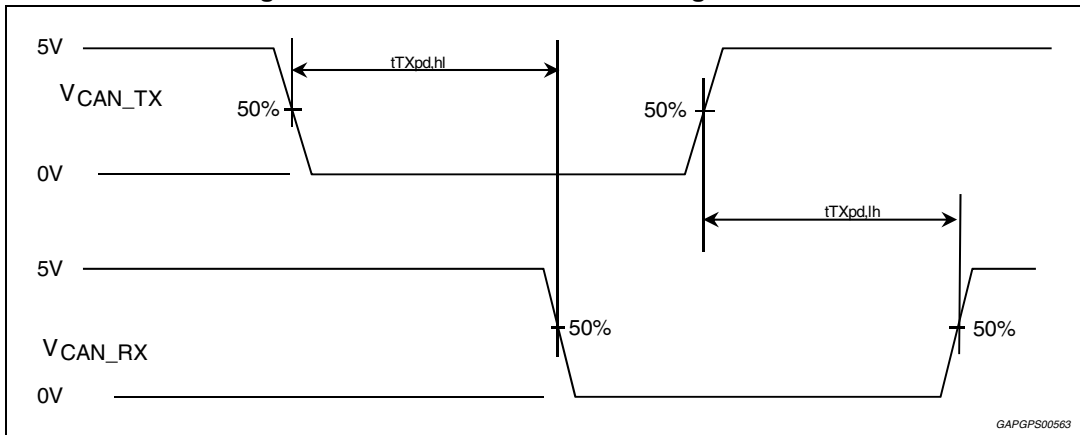
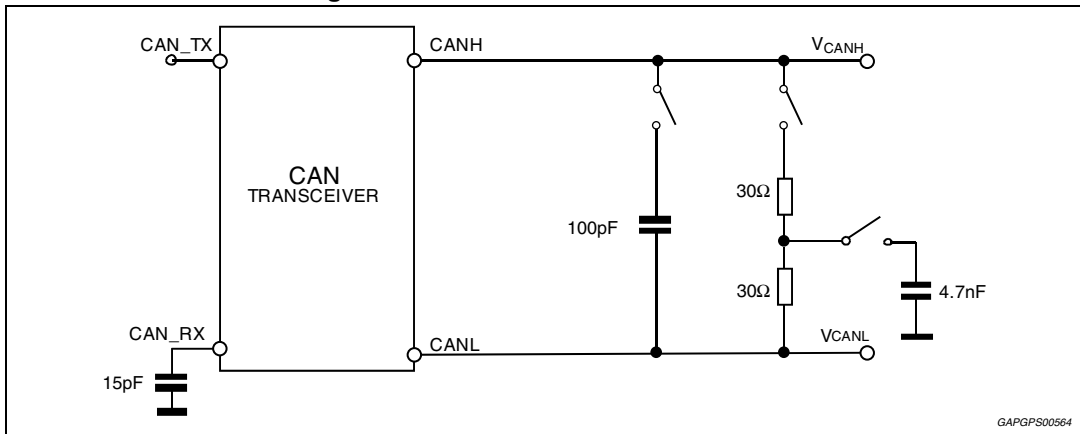
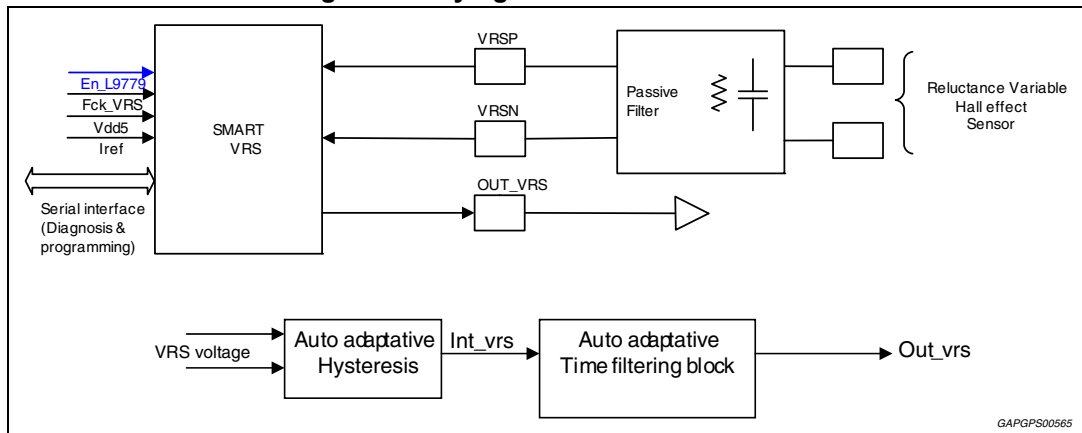


Figure 58. CAN transceiver test circuit



## 6.14 Flying wheel interface function

Figure 59. Flying wheel interface circuit



### 6.14.1 Flying wheel interface functionality description

The flying wheel interface is an interface between the microprocessor and the flying wheel sensor: it handles signals coming from magnetic pick-up sensor or Hall Effect sensor and feeds the digital signal to Microcontroller that extracts flying wheel rotational position, angular speed and acceleration.

This circuit implements an auto adaptive hysteresis and filter time algorithm that can be configured via SPI using VRS\_mode bit.

If the auto adaptive hysteresis is OFF the hysteresis value can be selected using VRS\_Hyst bit.

If fault is present (OL / SC GND / SC VB) the functionality is not guaranteed.

### 6.14.2 Auto-adaptive sensor filter

Two main VRS configuration sets are available for VRS, by means of CONFIG\_REG1 register: fully adaptive VRS mode (default) and limited adaptive VRS mode.

#### Auto-adaptive hysteresis (fully adaptive mode)

When enabled the auto adaptive hysteresis works as described below.

Input signals difference is obtained through a full differential amplifier; its output, DV signal, is fed to peak detection circuit and then to A/D converter implemented with 4 voltage comparators (5 levels) (Pvi).

Output of A/D is sent to Logic block ([Table 43: Hysteresis threshold precision](#)) that implements correlation function between Peak voltage and hysteresis value; hysteresis value is used by square filtering circuit which conditions DV signal.



Figure 60. Auto adaptive hysteresis diagram

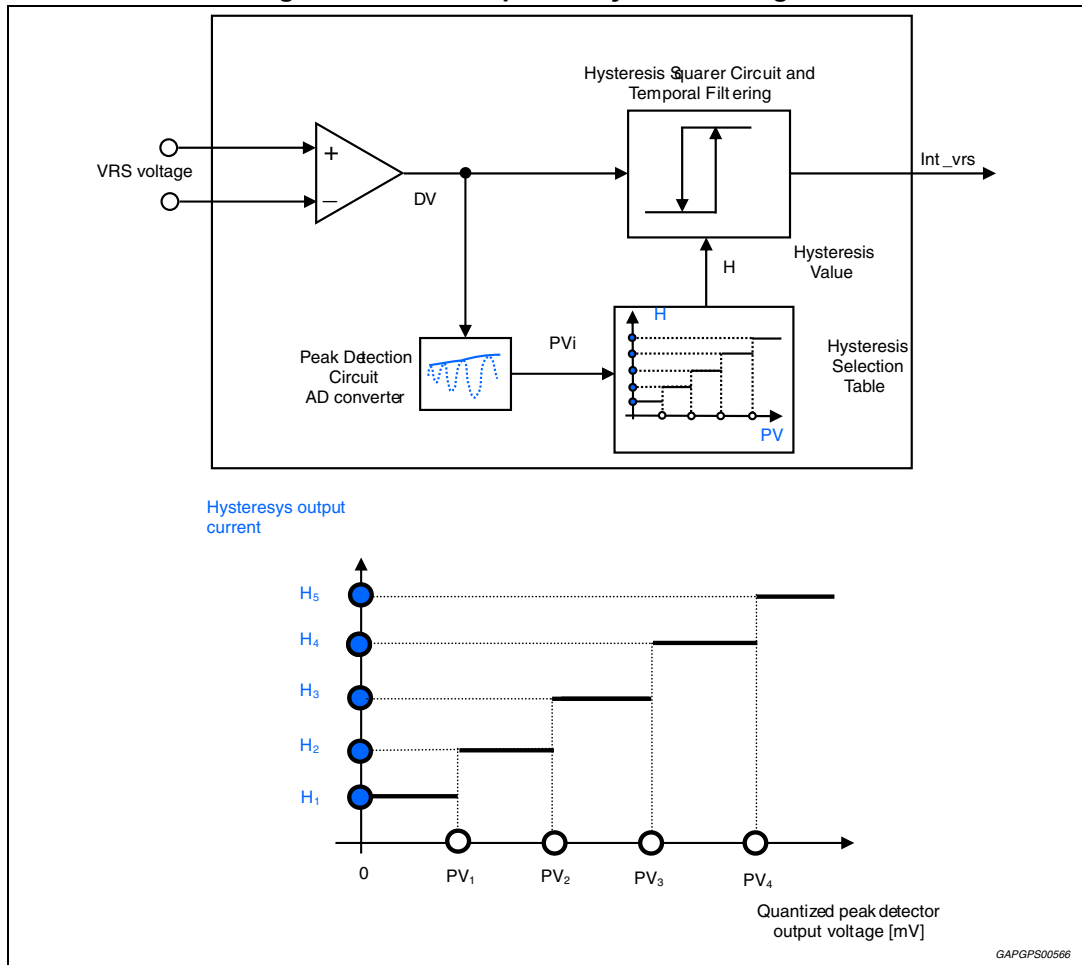
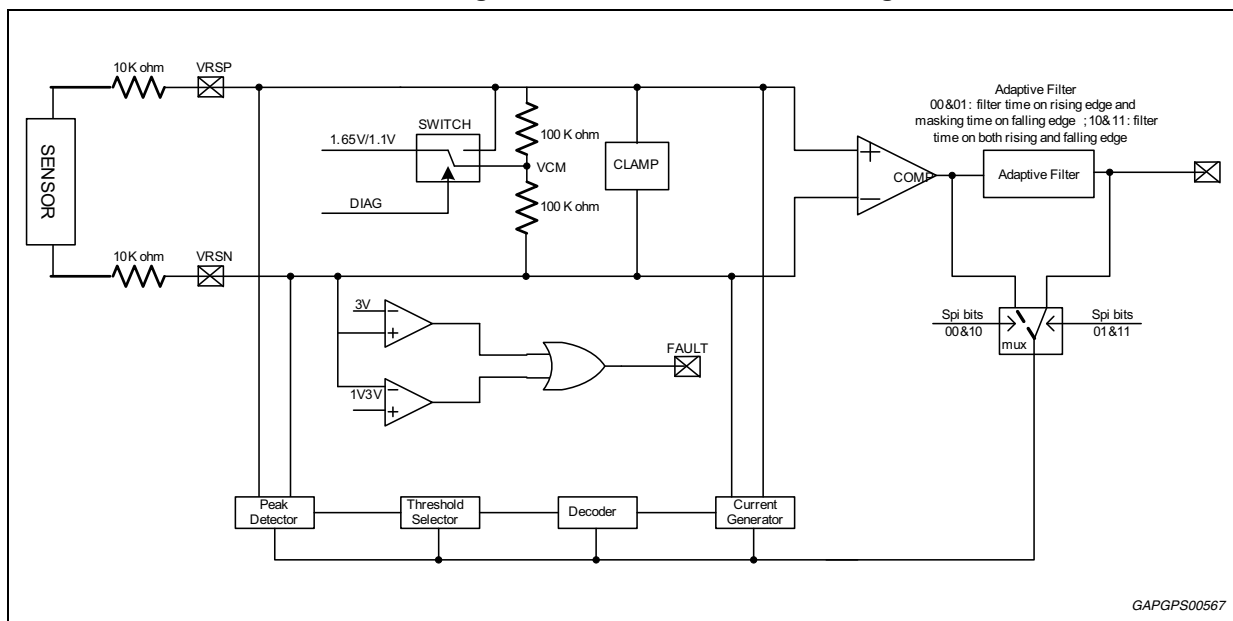


Figure 61. VRS interface block diagram



**Table 42. Pick voltage detector precision**

| Pick voltage [PV] | Min  | Typ  | Max  | Unit |
|-------------------|------|------|------|------|
| PV1               | 600  | 930  | 1300 | mV   |
| PV2               | 1200 | 1600 | 1950 | mV   |
| PV3               | 1990 | 2300 | 2600 | mV   |
| PV4               | 2660 | 3000 | 3380 | mV   |

**Table 43. Hysteresis threshold precision**

| Hysteresis current [H] | Value |     |      | Unit | Correspondent value on 20 kΩ ext. resistor | Unit |
|------------------------|-------|-----|------|------|--|------|
|                        | Min   | Typ | Max  |      | Typ  |      |
| HI1                    | 3     | 5   | 7    | μA   | 100  | mV   |
| HI2                    | 7     | 10  | 13.5 | μA   | 200  | mV   |
| HI3                    | 12.8  | 17  | 23   | μA   | 347  | mV   |
| HI4                    | 23    | 32  | 41   | μA   | 644  | mV   |
| HI5                    | 35    | 51  | 65   | μA   | 1020                                       | mV   |

*Note:* For a single IC, there is no overlap of parameters PVX (PV1<PV2<PV3<PV4) and HIX(HI1<HI2<HI3<HI4<HI5), which are guaranteed by design

**Auto-adaptative time filter (fully adaptive mode)**

This characteristic is useful to set the best internal filter time depending on the input signal frequency.

Tfilter time depends on duration of the previous period Tn according to the following formula:

$$T_{filter(n+1)} = 1/32 * T_n \text{ if } Int\_vrs > T_{filter(n)}$$

The filtering time purpose is filtering very short spikes.

The digital filtering time is applied to internal squared signal (int\_vrs), obtained by Voltage comparators.

The output of time filtering block is out\_vrs signal.

The filtering time Tfilter is applied to int\_vrs signal in two different ways:

- Rising edge: if int\_vrs high level lasts less than Tfilter out\_vrs is not set to high level  
In absence of any spikes during input signal rising edge out\_vrs signal is expected with a delay of Tfilter time
- Falling edge: the falling edge of int\_vrs is not delayed through time filtering block: after falling edge for a time Tfilter any other transition on int\_vrs signal is ignored.

Tmaxfilter = 200 μs typ.

Tmin filter = 4 μs typ.

The default value after reset is Tmaxfilter.

The Tfilter function is reset by the enable of FLYING WHEEL function.

Figure 62. Auto-adaptive time filter (rising edge)

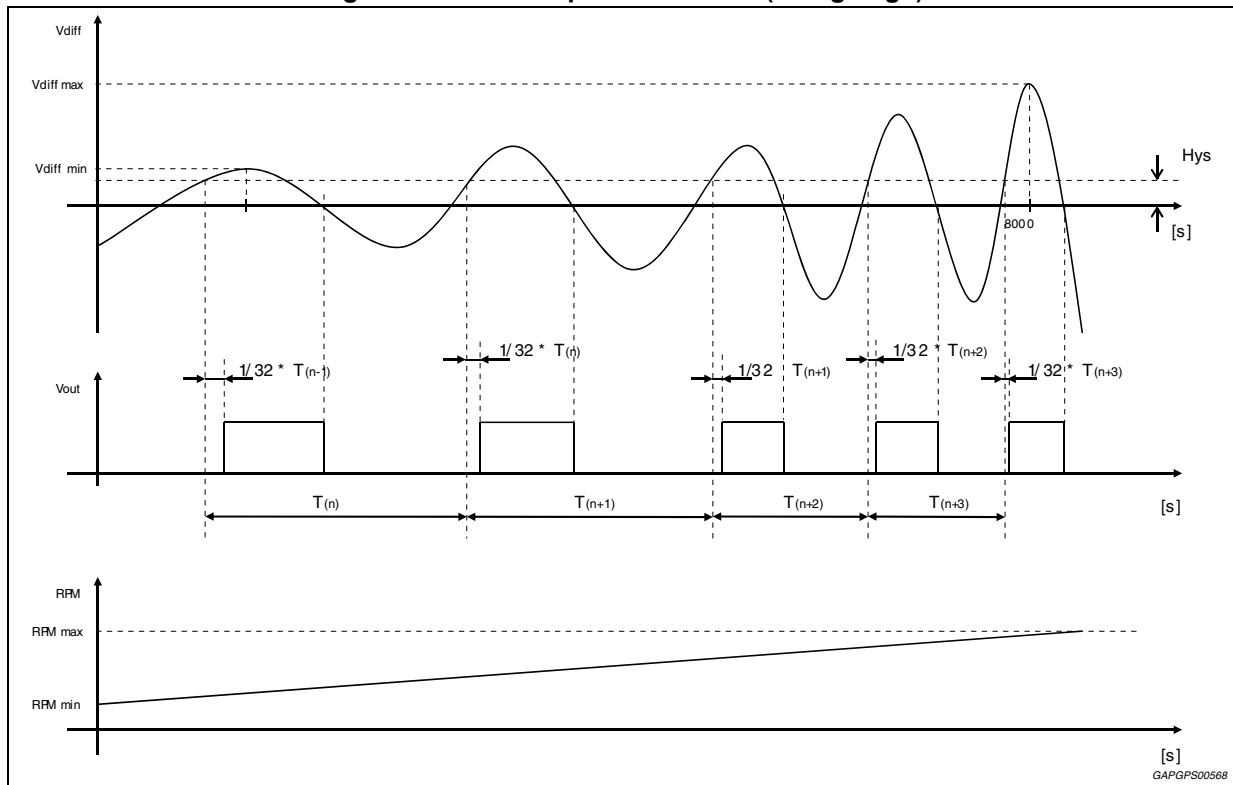
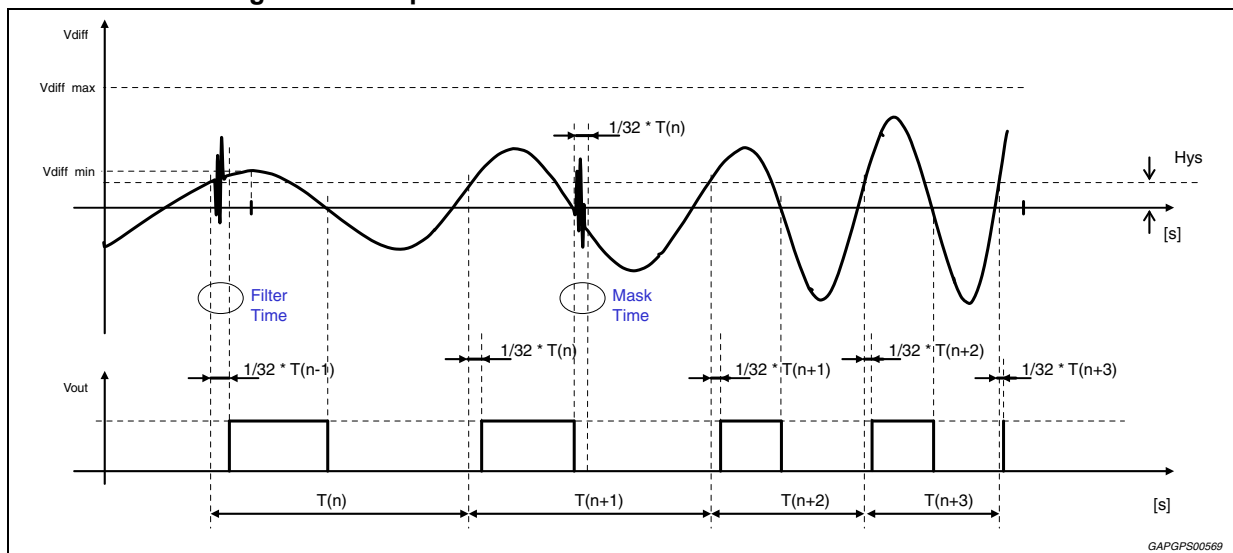


Figure 63. Adaptive filter function when the SPI bit are 00 or 01



Software option configuration requirement for VRS function:

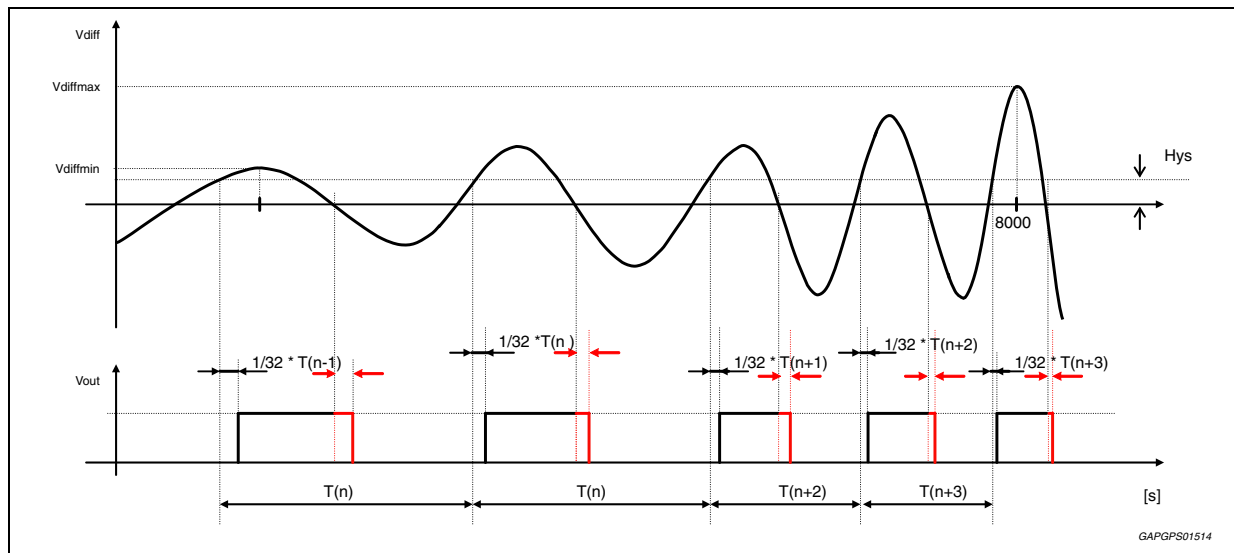
- By SPI command it is possible to configure different options of the VRS function:
- The hysteresis changing is driven by a feedback signal coming from COMP output OR from adaptive filter
  - The adaptive filter can be either on the rising edge or on both edges of the VRS output.

**Table 44. SPI command possible configuration of different option of VRS function**

| SPI Bit  | 00   | 01  | 10  | 11 <sup>(1)</sup>  |
|----------|--|---|---|--|
| Function | Feed back from COMP output. VRS input signal from low to high, add $1/32 * T_n$ filter time. VRS output from high to low with $1/32 * T_n$ masking time. | Feed back from after adaptive filter block instead of from COMP output (specifically as shown in Figure 64) VRS output signal from low to high, add $1/32 * T_n$ filter tune. VRS output from high to low with $1/32 * T_n$ masking time. | VRS input signal from high to low, add $1/32 * T_n$ filter time. VRS output from high to low with $1/32 * T_n$ filter time. | Realize 01 and 10 functions Feed back from after adaptive filter block instead of from COMP output. VRS output signal from low to high, add $1/32 * T_n$ filter time. VRS output from high to low with $1/32 * T_n$ filter time. Feed back from after adaptive filter block instead of from COM output. VRS output signal from low to high, add $1/32 * T_n$ filter time. VRS output from high to low with $1/32 * T_n$ filter time. |

1. If SPI CONFIG\_REG7-bit4 is set (High) VRS filter time is fixed to  $4 \mu s \pm 1.25 \mu s$ .

**Figure 64. Adaptive Filter Function when the SPI bit are 10 or 11**



**Limited adaptive mode**

Auto time adaptive filter is fixed to  $4 \mu s$  (typical).

Auto amplitude adaptive filter is limited to a minimum hysteresis as set by related VRS register.

Note that in case the VRS input amplitude is persistently lower than the minimum hysteresis setting, VRS output deadlock can be removed by setting CONFIG\_REG5 bit5 to 1, which forces the hysteresis to 5  $\mu$ A. This procedure is not glitch free. Once a new minimum hysteresis value has been set, CONFIG\_REG5 bit5 must return to 0.

VRS diagnostic is not available when limited adaptive mode is selected.

### 6.14.3 Application circuits

Figure 65. Variable reluctance sensor

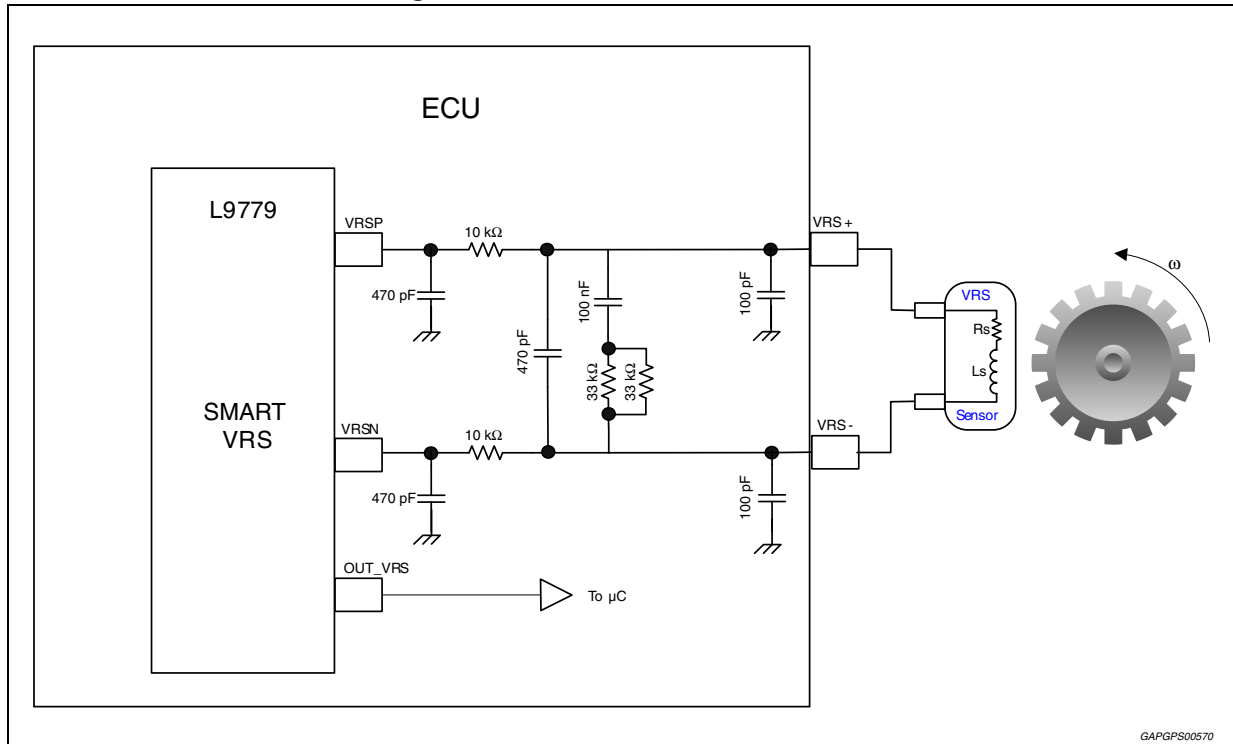


Figure 66. VRs typical characteristics

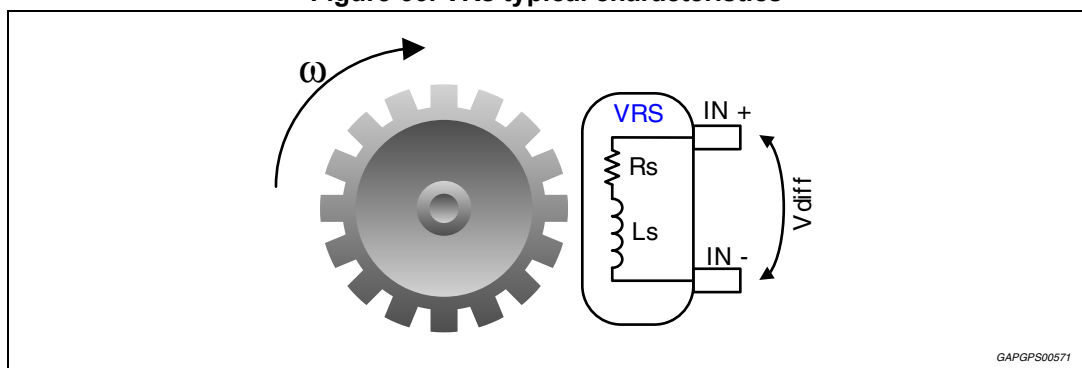
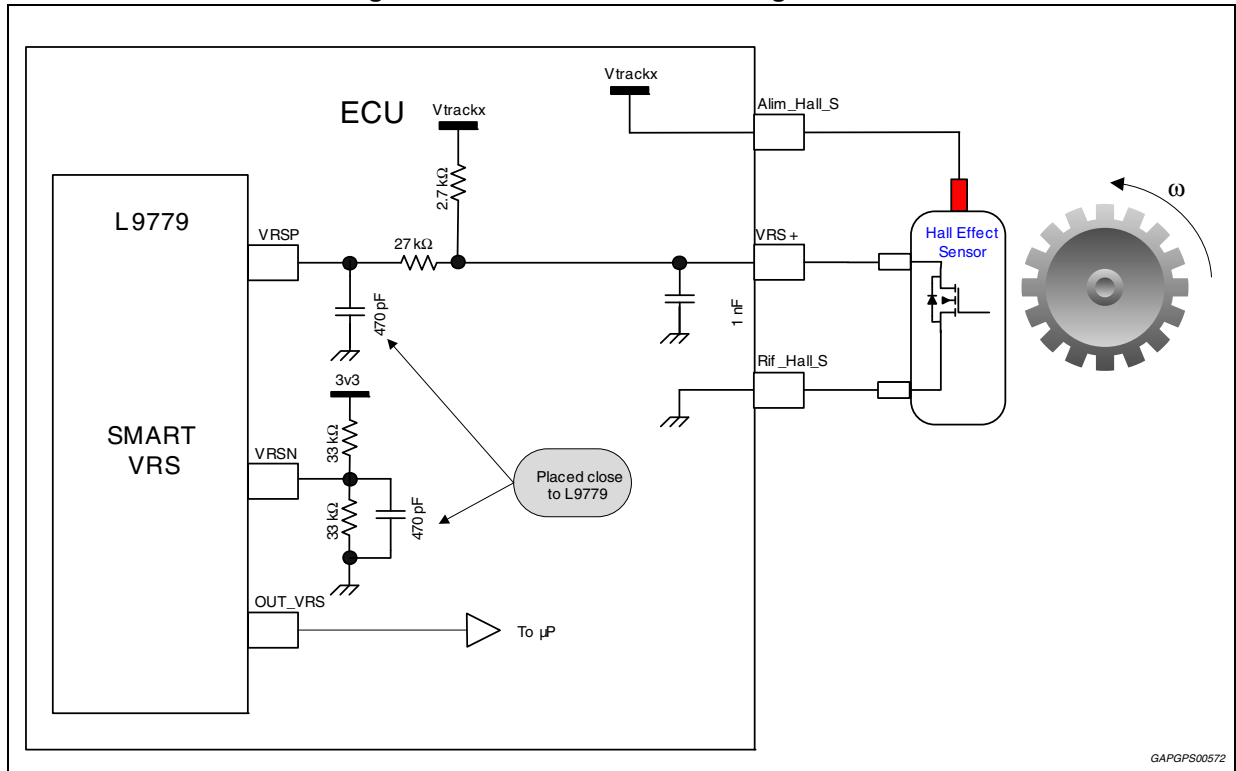


Table 45. VRs typical characteristics

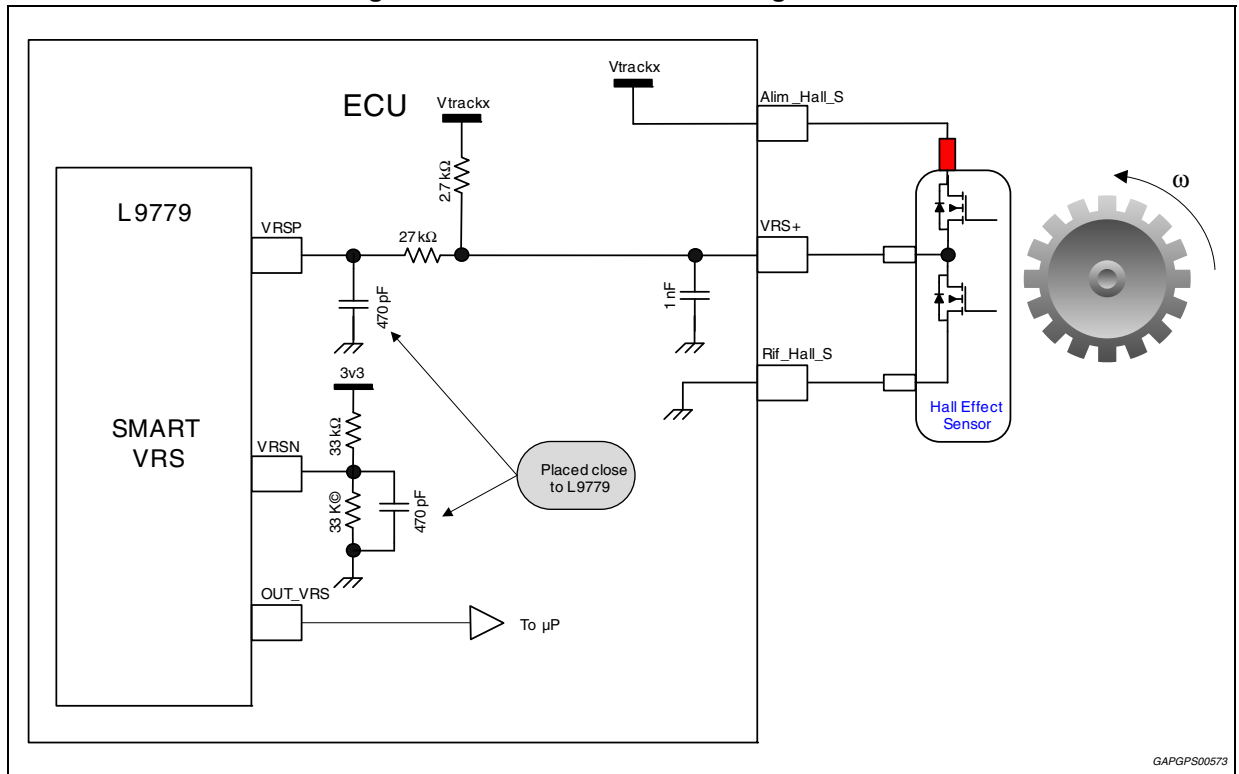
| Symbol | Parameter             | Min  | Typ | Max  | Unit     |
|--------|-----------------------|------|-----|------|----------|
| Rs     | Sensor resistance     | 300  | 600 | 1000 | $\Omega$ |
| Ls     | Sensor inductor       | -    | 250 | -    | mH       |
| Vdiff  | Sensor output voltage | -200 | -   | +200 | V        |
| Tout   | Output period         | 5000 | -   | 100  | $\mu$ s  |

Figure 67. Hall effect sensor configuration 1



GAPGPS00572

Figure 68. Hall effect sensor configuration 2



### 6.14.4 Diagnosis test

After the request of diagnosis by SPI, the diagnosis routine tests the sensor presence or vacancy and the short circuit to GND or Vbat. When the system is in diagnosis status the flying wheel interface function doesn't operate. The diagnosis procedure has an operation time of about min 5ms due to the external transient

The result of diagnosis routine is valid only if the engine is switched off and if the sensor is a variable reluctance sensor.

In the last operation of the diagnosis protocol writes the diagnosis result in VRSdiag bit and writes the operative status in VRSstatus bit. If a new request is sent the new value is overwritten.

Figure 69. Diagnosis test diagram

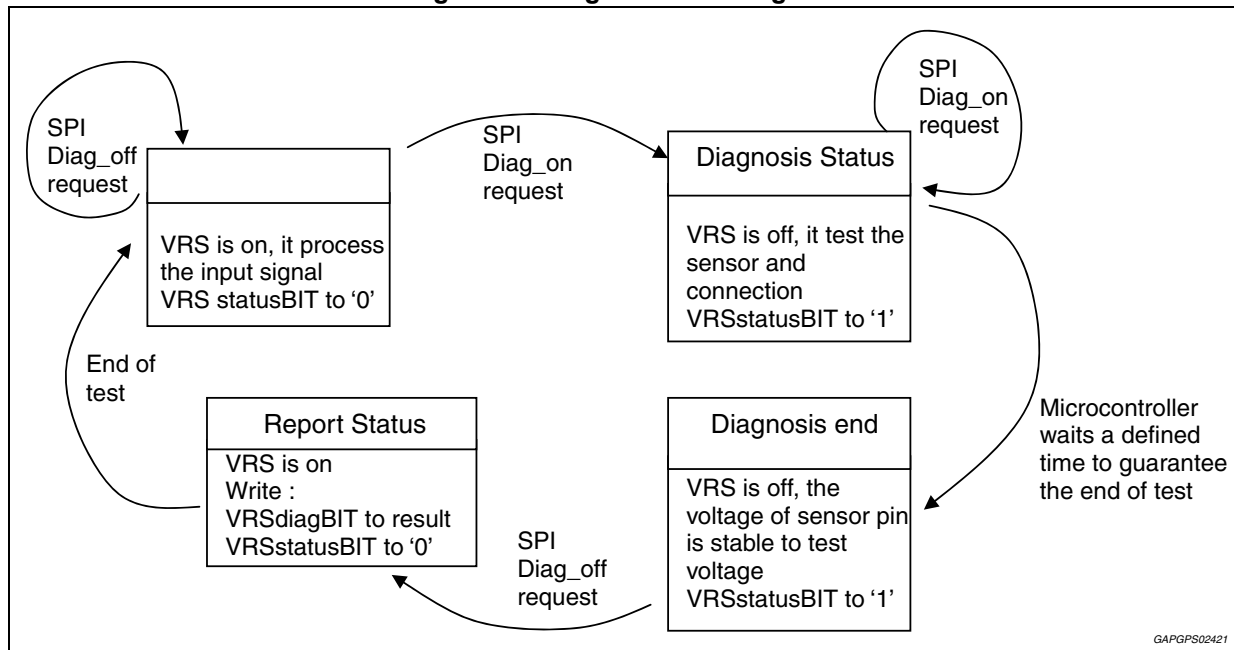


Table 46. Diagnosis test electrical characteristics

| Pin          | Symbol         | Parameter  | Test condition                                      | Min      | Typ      | Max      | Unit |
|--------------|----------------|--|---|----------|----------|----------|------|
| VrsP<br>VrsM | $V_{iThL}$     | Input high-to-low differential threshold voltage | -   | -50      | 0        | 50       | mV   |
|              | $V_{CM}$       | Common mode operating range                      | Not to be tested. It is an application note.        | 0        | 1.65     | 3        | V    |
|              | $V_{clpH}$     | Input high clamping voltage                      | $ VRS\_INP  =  VRS\_INM  = 20\text{ mA}$            | 3.3 -0.3 | -        | 3.3 +0.3 | V    |
|              | $V_{clpL}$     | Input low clamping voltage                       | $ VRS\_INP  =  VRS\_INM  = 20\text{ mA}$            | -1.5     | -        | -0.3     | V    |
|              | $V_{openload}$ | Output open load voltage                         | $VRS\_INP = VRS\_INM$ $V_{openload}$ Mode R enabled | 1.5      | (3.3) /2 | 1.8      | V    |



Table 46. Diagnosis test electrical characteristics (continued)

| Pin               | Symbol                         | Parameter   | Test condition                                   | Min            | Typ     | Max | Unit    |         |
|-------------------|--------------------------------|---|--|----------------|---------|-----|---------|---------|
| VrsP              | $I_{bvrsp}$                    | Input bias current<br>Vrsp  | VRS_INP = Vopenload<br>Mode R enabled            | -              | -       | 2   | $\mu$ A |         |
| VrsM              | $I_{bvrsM}$                    | Input bias current<br>V <sub>rsm</sub>                              | VRS_INM = Vopenload<br>Mode R enabled            | -              | -       | 2   | $\mu$ A |         |
| Out_<br>Vrs       | $V_{OL}$                       | Output low<br>voltage   | VDD_IO = 5 V or 3.3 V<br>Isink current = 2 mA    | -              | -       | 0.5 | V       |         |
|                   | $V_{OH}$                       | Output high<br>voltage  | VDD_IO = 5 V or 3.3 V<br>Isource current = 2 mA  | VDD_IO<br>-0.5 | -       | -   | V       |         |
|                   | $I_{lk\_outvrs}$               | Input leakage<br>current to GND                                     | -  | -              | -       | -   | 1       | $\mu$ A |
|                   |                                | Input leakage<br>current to<br>VDD_IO                               | -  | -              | -       | -   | 1       | $\mu$ A |
|                   | $T_{d\_on\_outvrs}$            | Delay on falling<br>edge  | Test Ext cap = 300pF                             | -              | -       | 1   | $\mu$ s |         |
|                   | $T_{d\_off\_outvrs}$           | Delay on rising<br>edge   | Input signal Tperiod = 4 ms                      | -              | -       | 150 | $\mu$ s |         |
|                   | $T_{r\_Out\_vrs}$              | MRX rise time   | Test Ext cap = 300pF                             | -              | -       | 150 | ns      |         |
| $T_{f\_Out\_vrs}$ | MRX fall time                  | Test Ext cap = 300pF  | -  | -              | 150     | ns  |         |         |
| VrsP<br>VrsM      | $V_{outdiag}$                  | Output diag<br>voltage  | Vrs_INP = open; diag mode                        | 0,9            | (3.3)/3 | 1.3 | V       |         |
|                   | $I_{outdiag}$                  | Output diag<br>Current  | Vrs_INP = open;<br>Vrs_INM = GND; diag mode      | 50             | 65      | 80  | $\mu$ A |         |
|                   | $V_{outsh}$<br>$V_{bdiag\ th}$ | Output Short-<br>circuit range to<br>VBAT<br>Open Load<br>threshold | Vrs_INP = open;<br>Vrs_INM = Vramp; diag mode    | 2,8            | 3       | 3,2 | V       |         |
|                   | $V_{outsh\ gnd\ diag\ th}$     | Output Short-to<br>GND range<br>threshold                           | Vrs_INP = open;<br>Vrs_INM = Vramp;<br>diag mode | 1.1            | 1.3     | 1.5 | V       |         |

Note: When VrsP and VrsM are both in input high clamping condition, the clamp voltage of VrsP is 30mV(typical) higher than VrsM.

## 6.15 Monitoring module (watchdog)

Table 47. WDA\_INT electrical characteristics

| Pin     | Symbol              | Parameter                 | Test condition   | Min  | Typ | Max              | Unit          |
|---------|---------------------|---------------------------|--|------|-----|------------------|---------------|
| WDA_INT | $V_{WDA\_low}$      | Output low voltage        | $3.5\text{ V} < VDD5$<br>$I_{WDA} < 4\text{ mA}$               | -    | -   | 0.4              | V             |
|         |                     |                           | $2.2\text{ V} < VDD5 < 3.5\text{V}$<br>$I_{WDA} < 1\text{ mA}$ | -    | -   | 0.4              | V             |
|         | $I_{WDA}$           | Input leakage current     | -  | -    | -   | 1                | $\mu\text{A}$ |
|         | $V_{WDA\_in\_low}$  | Input voltage low level   | -  | -0.3 | -   | 1.1              | V             |
|         | $V_{WDA\_in\_high}$ | Input voltage high level  | -  | 2.3  | -   | $VDD_{IO} + 0.3$ | V             |
|         | $V_{WDA\_in\_hys}$  | Input voltage hysteresis  | -  | 300  | -   | 800              | mV            |
|         | $R_{pullup}$        | Internal pull-up resistor | -  | 50   | -   | 150              | k $\Omega$    |
|         | $f_{CLK1}$          | WDA clock CLK1            | -  | -5%  | 64  | 5%               | kHz           |

### 6.15.1 WDA - Watchdog (algorithmic)

#### Basic feature

Via SPI bus a WDA "question" must be read from a SPI register. A correct response must be written back via SPI in a well defined timing. If response or timing is not correct, then the WDA error counter EC is increased. If the error counter is increased to values greater than 4, some output functions are shut off. If the error counter reaches values greater than 7 (overflow), then a RST reset may be generated if this is previously configured via SPI.

On the other way round, with a RST event also the WDA output pin goes to low.

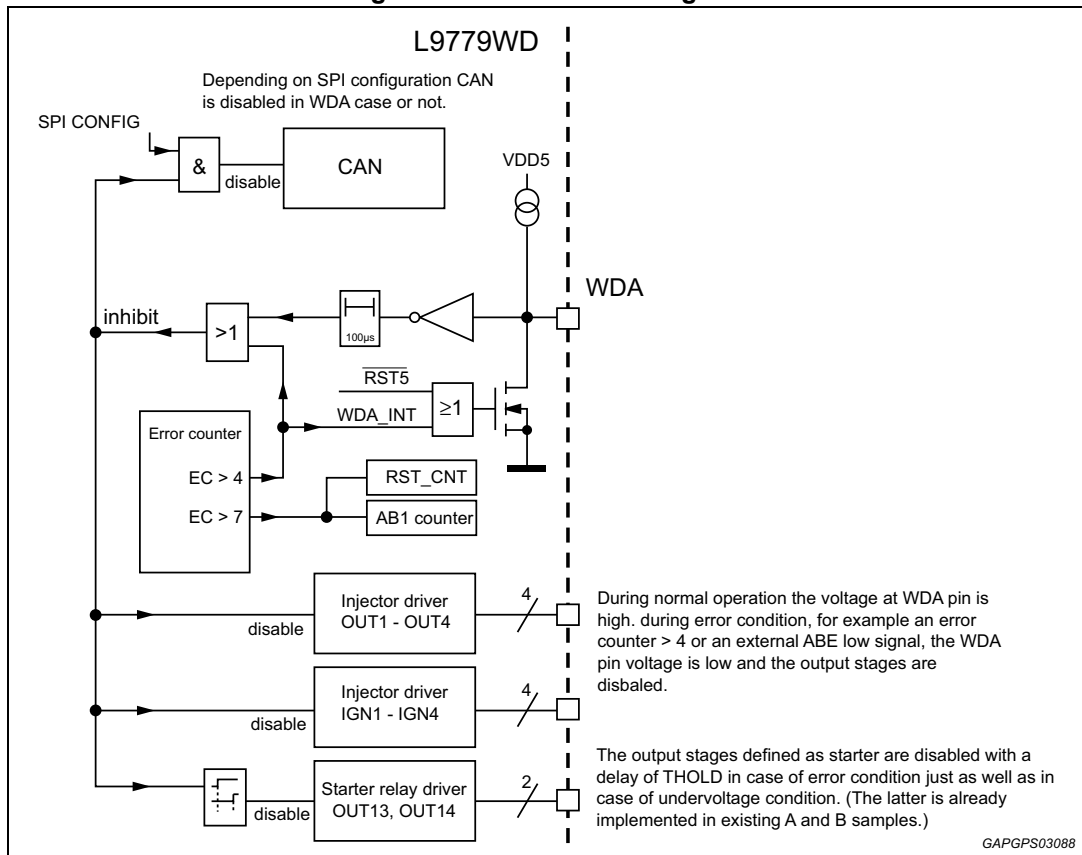
Note that after startup, reset or an overflow the initial value of the error counter is 6.

If WDA resets are enabled via SPI: The number of RST events generated by an error counter overflow is limited by the reset counter RST\_CNT. If RST\_CNT reaches the value of 7, then RST resets via WDA are no longer generated.

In case many WDA events occur during after-run power latch mode, the power latch mode is terminated by the AB1 counter: With each error counter overflow, the AB1 counter is increased. If it reaches a value greater than 7, then the after-run power latch mode is terminated.

6.15.2 Monitoring module - WDA Functionality

Figure 70. WDA block diagram



Each time the watchdog error counter is  $EC > 7$  the AB1-counter AB1\_CNT increases. When this counter is  $AB1\_CNT = 7$  and a further error occurs, the after-run will be terminated. The AB1-counter is not cleared when  $EC < 7$ . AB1-counter is cleared when  $EC < 5$  and  $\langle WDA\_INT \rangle = '0'$ , and is reset by RST\_UV.

The monitoring module works independently of the controller functionality. The monitoring module generates various questions, which the controller must fetch and correctly respond to within a defined time window. The monitoring module checks whether the response is returned in a time window and if the response is fully correct.

The question is a 4-bit word. This 4-bit word can be fetched by the controller using a read access to register REQULO. The monitoring module also calculates the expected correct response, which is compared to the actual response from the controller.

The response is a 32-bit word consisting of the 4 bytes RESP\_BYTE3, RESP\_BYTE2, RESP\_BYTE1 and RESP\_BYTE0. The 4 bytes are sent to the monitoring module via SPI in the order RESP\_BYTE3 - RESP\_BYTE2 - RESP\_BYTE1 - RESP\_BYTE0 using four times the command WR\_RESP - once for each answer byte.

The monitoring cycle is started by (the end of) writing of RESP\_BYTE0 (least significant response byte) or by a write access to the RESPTIME register. The cycle starts with a variable wait time (response time, set by register RESPTIME), followed by a fixed time window. When a monitoring cycle ends (the end of the fixed time window has been reached) a new monitoring cycle is started automatically.

A correct response within the time window (at a response time > 0ms) decreases an ERROR COUNTER by one. An incorrect response, a response outside the time window or response time = 0ms leads to the incrementing of the ERROR COUNTER by one.

" within the time window" means that the end of writing the last answer byte - i.e. RESP\_BYTE0 - falls into the fixed time window mentioned above (see picture below). Except the last answer byte, the previous answer bytes may also be written earlier than the beginning of the time window.

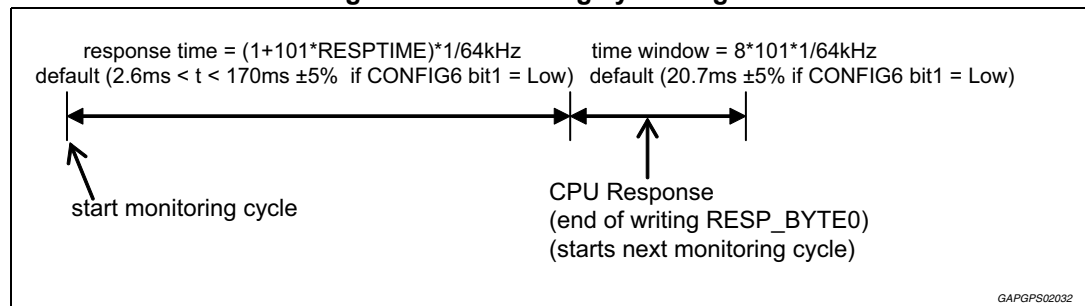
The question sequence is deterministic. A question will be repeated until it is answered correctly both in value and in time. Then the next question is placed in the sequence.

The ERROR COUNTER (EC) is a 3-bit counter. Various actions are activated depending on the value of the counter.

The result of the comparison of the controller response and the calculated correct response, as well as the next question, are available in the registers REQUHI/REQULO after receiving the µC response (LSB of RESP\_BYTE0) and can be read by the controller.

### Monitoring cycle

Figure 71. Monitoring cycle diagram



### Generating questions

The generation of the 4-bit question (REQU [3-0]) is realized with a 4-bit counter and a 4-bit Markov chain. The 4-bit counter only changes into the next state during the sequencer-run when the previous question has been answered correctly in value and in time.

The Markov chain changes into the next state on the 1111b -> 0000b transition of the 4-bit counter if the previous question has been answered correctly in value and in time.

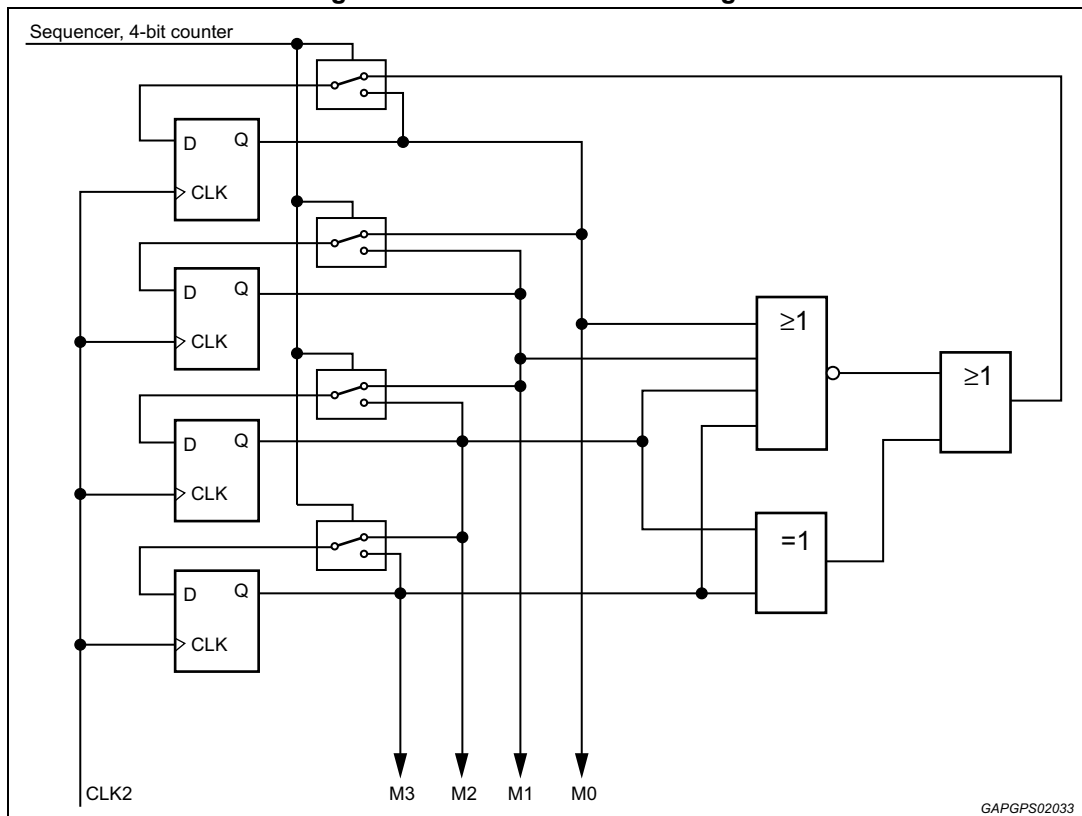
Neither the counter state nor the Markov chain states are changed by a sequencer-run because of a write-access to the RESPTIME register or the expiration of the time window.

The 4-bit counter and Markov chain are set to 0000b when RST\_UV is active.

The singularity of the Markov chain is 0000b. To leave the singularity (after power-up, error state), the feedback path (M3 + M2 + M1 + M0) is realized. The "real" feedback logic of the Markov chain is the XOR gate (M3 XOR M2).

The following diagram shows the 4-bit Markov chain.

Figure 72. 4-bit Markov chain diagram



Combining the 4-bit counter and Markov chain to the 4-bit question:

- $REQU0 = M1 \text{ XOR } Z1$
- $REQU1 = M3 \text{ XOR } Z3$
- $REQU2 = M0 \text{ XOR } Z0$
- $REQU3 = M2 \text{ XOR } Z2$ .

**ERROR COUNTER (EC) and reactions, AB1 COUNTER (AB1\_CNT) and generation of the monitoring module reset**

Various actions are initiated for specific counter states of the ERROR COUNTER EC. The counter reset state is 6.

For ERROR COUNTER (EC) > 4, <WDA\_INT> is set to '1', thus activating the open-drain output [WDA] that is low-active.

**Table 48. Error counter**

| ERROR COUNTER | 0 ... 4             | 5                 | 6 ... 7           | Over flow EC > 7  |
|---------------|---------------------|-------------------|-------------------|---|
| WDA_INT       | low – i.e. '0'      | high – i.e. '1'   | high – i.e. '1'   | high – i.e. '1'   |
| [WDA]         | inactive – i.e. '1' | active – i.e. '0' | active – i.e. '0' | active – i.e. '0'   |
| AB1-COUNTER   | 0                   | unchanged         | unchanged         | incremented by 1  |
| AB1           | low – i.e. '0'      | unchanged         | unchanged         | AB1_CNT < 7: low<br>AB1_CNT 6 → 7: low<br>AB1_CNT 7 → 7: high |

**Shutdown in an error state in "afterrun"**

If the ERROR COUNTER reaches the value "7" and a further error occurs the AB1 COUNTER AB1\_CNT is incremented by one during a sequencer-run.

The state "EC = 7 and a further error occurs" is also called ERROR COUNTER overflow ("EC" > 7).

If ERROR COUNTER > 4 AND a soft-reset is detected then the COUNTER AB1\_CNT is also incremented by one. The counter AB1\_CNT is a 3 bit counter.

Behaviour of AB1\_CNT:

- asynchronous reset to "000" with RST\_UV
- synchronous reset to "000" IF <WDA\_INT> = LOW (EC < 5)
- IF (AB1\_CNT < 7) AND ((sequencer-run AND "EC" > 7) OR soft-reset) THEN  
AB1\_CNT = AB1\_CNT + 1  
ELSE unchanged.

The counter cannot be decremented and can be only reset to "000" by an active RST\_UV signal (asynchronous) or <WDA\_INT> = '0' (synchronous).

The signal AB1 becomes active '1' when AB1\_CNT = "111" and a further error is detected when the sequencer runs or when AB1\_CNT = "111" and a soft-reset is detected.

In "afterrun", the active AB1 signal causes a shut-down of the main relay and the voltage regulators. This function ensures a secure shutdown of the system in an error state of the µC in "afterrun".

Behaviour of AB1:

- asynchronous reset to "0" with RST\_UV
- synchronous reset to "0" IF <WDA\_INT> = '0' (EC < 5)
- IF (AB1\_CNT = 7) AND ((sequencer-run AND further error) OR soft-reset) THEN  
 AB1 = 1  
 ELSE unchanged.

**Generation of a monitoring module reset**

The monitoring module may cause a reset at the pin [RST] named "monitoring module reset" in conjunction with the internal signal WD\_RST. The generation of a monitoring module reset depends on the state of the bit <INIT\_WDR>.

**<INIT\_WDR> = '0' (reset state):**

If <INIT\_WDR> = '0', the signal <WD\_RST> remains always inactive '0' and the monitoring module can never generate a reset. The error counter can only be decremented via correct responses. If <INIT\_WDR> = '0' the state of the reset counter <RST\_CNT> remains unchanged when an ERROR COUNTER overflow occurs (description of the reset counter <RST\_CNT> see below).

**<INIT\_WDR> = '1':**

If <INIT\_WDR> = '1', an ERROR COUNTER overflow activates a reset [RST] (signal <WD\_RST> becomes active). The signal <WD\_RST> becomes active (i.e. '1') due to an ERROR COUNTER overflow when the value of the 3 bit reset counter <RST\_CNT(2-0)> is 0..6. If the value of <RST\_CNT> = "111" and an ERROR COUNTER overflow occurs <WD\_RST> remains inactive (i.e. '0') and no reset is generated.

The "reset counter" <RST\_CNT> is incremented by one during a sequencer-run due to an ERROR COUNTER overflow when <INIT\_WDR> = '1' and <RST\_CNT> is between 0 and 6. If <RST\_CNT> = 7 and an ERROR COUNTER overflow occurs, the counter state remains 7. The counter can not be decremented and can only reset to zero by an active RST\_UV signal.

The occurrence of a monitoring module reset is indicated via the flag <WDG\_RST> = '1'. Reading the flag via SPI clears it automatically.

In effect maximum 7 monitoring module resets can be generated between 2 active RST\_UV signal. (see also state table for <INIT\_WDR> = '1' below).

The state of the "reset counter" <RST\_CNT> can be read via SPI but cannot be changed.

**Table 49. State for <INIT\_WDR> = 1**

| RST_CNT old | "EC" > 7 and sequencer-run | RST_CNT new        | WD_RST                            |
|-------------|----------------------------|--------------------|-----------------------------------|
| 000 .. 111  | no                         | = RST_CNT old      | '0', no monitoring module reset   |
| 000 .. 110  | yes                        | = RST_CNT old + 1  | '1', thus monitoring module reset |
| 111         | yes                        | = RST_CNT old =111 | '0', no monitoring module reset   |

In a factory testmode the pin [WDA] is always active '0'; the internal signal <WDA\_INT> is not changed by the factory testmodes.

*Note: There is no impact on internal power stages from active pin [WDA] in factory testmode.*



**Table 50. Reset-behaviour of <WDA\_INT>, AB1 and <WD\_RST>**

| Signal  | Reset source | Reset state                 |
|---------|--------------|-----------------------------|
| WDA_INT | RST_UV       | '1', i.e. pin WDA is active |
| AB1     | RST_UV       | '0', i.e. inactive          |
| WD_RST  | RST_UV       | '0', i.e. inactive          |

**Response comparison**

The 2-bit counter <RESP\_CNT (1-0)> counts the received bytes of the 32-bit response and controls the generation of the expected response. Its default value is "11" (corresponds to "waiting for RESP\_BYTE3").

The <RESP\_ERR> flag is set '1' when a response byte is incorrect. The flag remains '0' if the 32-bit response is correct. The ERROR COUNTER is updated with the flag. The default state of the flag is '0'.

The 2-bit counter <RESP\_CNT(1-0)> and the <RESP\_ERR> flag are reset to their corresponding default values at a sequencer-run. The reset condition of the counter <RESP\_CNT (1-0)> and the <RESP\_ERR> flag are the corresponding default states.

Procedure of the sequential response comparison:

<RESP\_CNT(1-0)> = "11": switch the expected response for RESP\_BYTE3 to the comparator

Write access: RESP\_BYTE3

Set <RESP\_CNT> to "10", update <RESP\_ERR> flag

<RESP\_CNT(1-0)> = "10": switch the expected response for RESP\_BYTE2 to the comparator

Write access: RESP\_BYTE2

set <RESP\_CNT> to "01", update <RESP\_ERR> flag

<RESP\_CNT(1-0)> = "01": switch the expected response for RESP\_BYTE1 to the comparator

Write access: RESP\_BYTE1

set <RESP\_CNT> to "00", update <RESP\_ERR> flag

<RESP\_CNT(1-0)> = "00": switch the expected response for RESP\_BYTE0 to the comparator

Write access: RESP\_BYTE0

Start sequencer (SEQU\_START signal), set <RESP\_CNT> to "11", update <RESP\_ERR> flag (update ERROR COUNTER)

Sequencer clears <RESP\_ERR> flag to '0'

SEQU\_START = ¬(RESP\_CNT1) AND ¬(RESP\_CNT0) AND "response byte write"



Expected Responses:

$RESP\_SOLL7 = REQU2 \text{ XOR } RESP\_CNT0$

$RESP\_SOLL6 = REQU0 \text{ XOR } RESP\_CNT0$

$RESP\_SOLL5 = REQU3 \text{ XOR } RESP\_CNT0$

$RESP\_SOLL4 = REQU1 \text{ XOR } RESP\_CNT0$

$RESP\_SOLL3 = ((REQU2 \text{ XOR } REQU0) \text{ XOR } REQU3) \text{ XOR } RESP\_CNT1$

$RESP\_SOLL2 = ((REQU0 \text{ XOR } REQU3) \text{ XOR } REQU1) \text{ XOR } RESP\_CNT1$

$RESP\_SOLL1 = ((REQU2 \text{ XOR } REQU0) \text{ XOR } REQU1) \text{ XOR } RESP\_CNT1$

$RESP\_SOLL0 = (RESP\_CNT1 \text{ XOR } REQU3) \text{ XOR } REQU0$

**Table 51. Expected responses**

| question REQU (3-0) | RESP_BYTE3 | RESP_BYTE2 | RESP_BYTE1 | RESP_BYTE0 |
|---------------------|------------|------------|------------|------------|
| 0                   | FF         | 0F         | F0         | 00         |
| 1                   | B0         | 40         | BF         | 4F         |
| 2                   | E9         | 19         | E6         | 16         |
| 3                   | A6         | 56         | A9         | 59         |
| 4                   | 75         | 85         | 7A         | 8A         |
| 5                   | 3A         | CA         | 35         | C5         |
| 6                   | 63         | 93         | 6C         | 9C         |
| 7                   | 2C         | DC         | 23         | D3         |
| 8                   | D2         | 22         | DD         | 2D         |
| 9                   | 9D         | 6D         | 92         | 62         |
| A                   | C4         | 34         | CB         | 3B         |
| B                   | 8B         | 7B         | 84         | 74         |
| C                   | 58         | A8         | 57         | A7         |
| D                   | 17         | E7         | 18         | E8         |
| E                   | 4E         | BE         | 41         | B1         |
| F                   | 01         | F1         | 0E         | FE         |

**Reset behaviour**

All monitoring module registers are reset by RST\_UV. The following monitoring module components are also reset by RST\_PRL:

**Table 52. Reset behaviour**

| Component:          | Reset Condition:          |
|---------------------|---------------------------|
| ERROR COUNTER       | 110b                      |
| Register for "EC>7" | ,0'                       |
| Register RESPTIME   | Maximum value: 0011 1111b |
| timer state         | "000...00"                |

*Note:* The signal RST\_PRL (partial reset) is active when RST or SW\_RST (Softreset) is active.

**Access during a sequencer-run**

A sequencer-run (which means the same as a monitoring cycle) is initiated by the writing of a response (i.e. all answer bytes <RESP\_BYTE3..0>) or a write to <RESPTIME> or by reaching "end of time window". It must not be interrupted by a new access, i.e. the monitoring module completes the action already started:

- A sequencer-run was initiated by a "response write": The sequencer completes its task with the data of the previous access and the new data are ignored.
- A sequencer-run was initiated by a "response-time write": The sequencer uses the response-time of the previous access, the error counter is correspondingly incremented by one and the <CHRT> bit (REQUHI register) is set and the new data are ignored. <CHRT> will be reset by reading and by the next start of a sequencer run (not reset by the sequencer run that is started by a "response-time write"!)
- A sequencer-run was initiated by "end of time window": The sequencer finishes the started run, the error counter is incremented by one and the new data are ignored.

The writing of a response-time during a sequencer-run must not set the <CHRT> bit (REQUHI register). The new response-time value is also not accepted. The writing of a response during a sequencer-run must not set the <W\_RESP> bit, the new response is also not accepted.

**Clock and time references**

The monitoring module must work independently of the micro-controller clock so that it can monitor the timing of the micro-controller. Therefore, a separate oscillator is necessary. This oscillator is integrated in the L9779WD-SPI and provides a clock CLK1 for the monitoring module. Clocked with CLK1, a divider generates the base time of  $101 \cdot 1/f\_clk = 101 \cdot 1/64\text{kHz} = 1.58 \text{ ms}$  for the response-time and  $8 \cdot 101 \cdot 1/64\text{kHz} = 8 \cdot 1.58 \text{ ms} = 12.6 \text{ ms}$  for the fixed time window. Accuracy of CLK1 is  $\pm 5\%$  (or better).

The response-time is adjustable by the controller in the range 0ms to about 100ms (register RESPTIME). The response-time can be calculated with the equation  $\text{response-time} = (1 + 101 \cdot \text{RESPTIME}) \cdot 1/f\_clk$  (where f\_CLK depends on CONFIG6 bit1 value: if High - default- f\_clk = 64 kHz, if Low f\_clk = 39 kHz).

The RESPTIME register is set to '0011 1111'b after a reset. The ERROR COUNTER is incremented by one if the controller changes the response-time. If the response-time is set



to 0ms, then the ERROR COUNTER is incremented by one even if a correct response is received within the time window. The maximum error reaction time is given by: maximum response-time, response at the end of a time-window and ERROR COUNTER 0 ' 5 \* (100ms + 12.6ms) = 563ms.

Note that clock-tolerances have to be taken into account additionally.

### **Watchdog influence on power up/down management unit**

The watchdog AB1 counter is increased every time the watchdog error counter is  $EC > 7$ , which means it has an overflow. If the AB1 counter reaches the value of 7 and a further error occurs, the system will be switched off same as it would happen in case of the already existing PWL\_EN\_TIMEOUTN signal.

### **Watchdog influence on smart power reset**

WDA has influence on the RST pin only if the WDA error counter is  $EC > 7$  and the resulting reset signal "WD\_RST" is enabled by SPI configuration bit "INIT\_WDR" in WR\_RESPTIME command.

### **Watchdog influence on Lsa functions ([Section 6.8.1](#))**

For Lsa functions OUT1, OUT2, OUT3, OUT4 (not OUT5).

In case of an internal WDA event (e.g. the WDA error counter is  $EC > 4$  which results in the signal WDA\_INT being set) or in case of the WDA pin being pulled low externally, the output stages OUT1, OUT2, OUT3, OUT4 go to inactive state.

### **Watchdog influence on LSd functions OUT13, OUT14 (starter relay drivers) [Section 6.8.4](#)**

In case of an internal WDA event (e.g. the WDA error counter is  $EC > 4$  which results in the signal WDA\_INT being set) or in case of the WDA pin being pulled low externally, the OUT13 and OUT14 stages go to inactive state after the time delay THOLD if the WDA event is still active.

### **Watchdog influence on Ignition drivers IGN1, IGN2, IGN3, IGN4**

In case of an internal WDA event (e.g. the WDA error counter is  $EC > 4$  which results in the signal WDA\_INT being set) or in case of the WDA pin is pulled low externally, the output stages go to inactive state.

### **Watchdog influence on CAN transceiver**

The WDA has influence on the CAN if the SPI configuration bit CAN\_TDI is set.

Once the CAN\_TDI bit is set, in case of an internal WDA event (e.g. the WDA error counter is  $EC > 4$  which results in the signal WDA\_INT being set) or in case of the WDA pin is pulled low externally, the CAN goes to receive-only mode (RxOnly).

## 6.16 Serial interface

The L9779WD-SPI offers the possibility to communicate with a  $\mu$ C using the Serial Peripheral Interface (SPI).

The serial communication is used:

- to set the parameter
- to read diagnosis
- to activate, to deactivate and to use the Query/Answer protocol
- to activate, to deactivate and to use the low side drivers
- to activate test mode (ST reserved)

### 6.16.1 SPI interface

The SPI interface consists of an input shift register, output shift register and four control signals. DIN is the data input to the input shift register. DO is the data output from the output shift register. SCK is the clock source input while CS is the active low chip select input.

### 6.16.2 SPI protocol

All SPI communications are executed in exact 16 bit increments. The L9779WD-SPI contains a data validation method through the SCK input to keep transmissions with not exactly 16 bits from being written to the device. The SCK input counts the number of received clocks and should the clock counter exceed or count fewer than 16 clocks, the received message is discarded without changes to internal registers.

The general format of the 16 bit transmission for global SPI interface is shown here below:

|            | D15       | D14    | D13    | D12    | D11    | D10    | D9  | D8   | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0     |
|------------|-----------|--------|--------|--------|--------|--------|-----|--|----|----|----|----|----|----|----|--------|
| <b>DIN</b> | X         | ADD(4) | ADD(3) | ADD(2) | ADD(1) | ADD(0) | X   | DATA IN or<br>SUBADDRESS (if ADD[4:0]= 0x10) |    |    |    |    |    |    |    | Parity |
| <b>DO</b>  | SPI error | ADD(4) | ADD(3) | ADD(2) | ADD(1) | ADD(0) | W/R | DATA OUT                                     |    |    |    |    |    |    |    | Parity |

Data to the device (i.e. DIN) consists of a five address bit, eight data bit and data parity. DIN data is the data to be written to the register indicated by address bit. Data returned from the device (i.e. DO) consists of SPI error bit, five address bit, eight data bit and data parity. DO data will be the contents of the register indicated by the address bits.

The communications is controlled through CS, enabling and disabling communication. When CS is at logic high, all SPI communication I/O is tri-stated and no data is accepted. When CS is low, data is latched on the rising edge of SCLK and data is shifted on the falling edge. The DIN pin receives serial data from the master with MSB first. Likewise for DO, data is read MSB first, LSB last. The failed transmission is indicated in the SPI\_ERR bit.

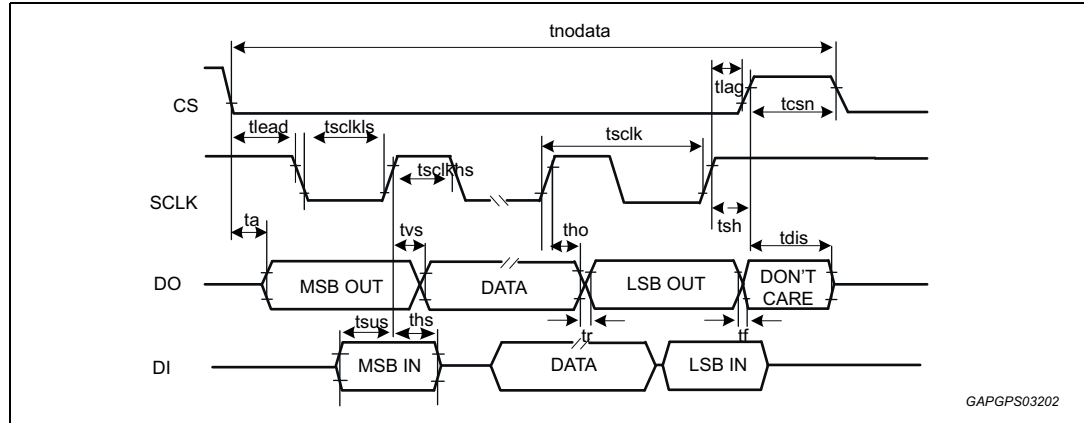
[Table 55](#) reports register addresses. Registers differ between write-only and read-only registers.

Write-only registers return all zeroes in MISO DO-DATA OUT field of next frame, with the exception of CLOCK\_UNLOCK\_RSRST and START\_REACT, which return LOCK and OUT\_DIS status bit.

Read-only registers (ID and Diagnostic) have unique address 0x10 and are selected by 5bit sub-address in MOSI DI-DATA IN field. MISO DO returns 1 at D9 bit and 5bit sub address in ADD[4:0] field.

**Timing characteristics**

**Figure 73. Timing characteristics diagram**



**Table 53. Timing characteristics**

| Symbol       | Parameter                      | Conditions         | Min | Max | Units   |
|--------------|--------------------------------|--------------------|-----|-----|---------|
| $f_{op}$     | Transfer frequency             | Design Information | -   | 8   | MHz     |
| $t_{sclk}$   | SCK period                     | Design Information | 125 | -   | ns      |
| $t_{lead}$   | Enable Lead time               | Design Information | 525 | -   | ns      |
| $t_{lag}$    | Enable lag time                | Design Information | 50  | -   | ns      |
| $t_{sklks}$  | SCK high time                  | Design Information | 38  | -   | ns      |
| $t_{sklks}$  | SCK low time                   | Design Information | 38  | -   | ns      |
| $t_{sus}$    | DIN input setup time           | Design Information | 20  | -   | ns      |
| $t_{th}$     | DIN input hold time            | Design Information | 20  | -   | ns      |
| $t_a$        | DO access time                 | 50 pF load         | -   | 60  | ns      |
| $t_{dis}$    | DO disable time                | 50 pF load         | -   | 100 | ns      |
| $t_{vs}$     | DO output valid time           | 50 pF load         | -   | 66  | ns      |
| $t_{tho}$    | DO output hold time            | 50 pF load         | 0   | -   | ns      |
| $t_r$        | DO rise time                   | 50 pF load         | -   | 30  | ns      |
| $t_f$        | DO fall time                   | 50 pF load         | -   | 30  | ns      |
| $t_{csn}$    | CS negated time                | Design Information | 640 | -   | ns      |
| $t_{sh}$     | SCK hold time                  | Design Information | 20  | -   | ns      |
| $t_{csgrt}$  | CS noise glitch rejection time | -                  | 50  | 300 | ns      |
| $t_{nodata}$ | SPI interframe time            | Design Information | 1.5 | -   | $\mu$ s |

**Electrical characteristics**

**Table 54. Electrical characteristics**

| Pin | Symbol            | Parameter            | Test condition         | Min       | Typ | Max       | Unit |
|-----|-------------------|----------------------|------------------------|-----------|-----|-----------|------|
| SCK | SCK <sub>L</sub>  | Low input level      | -                      | -0.3      | -   | 1.1       | V    |
|     | SCK <sub>H</sub>  | High input level     | -                      | 2.3       | -   | VDD5 +0.3 | V    |
|     | V <sub>HYST</sub> | Hysteresis           | -                      | 0.1       | -   | -         | V    |
|     | I <sub>IN</sub>   | Input current        | -                      | -         | -   | 5         | µA   |
| DIN | SCK <sub>L</sub>  | Low input level      | -                      | -0.3      | -   | 1.1       | V    |
|     | SCK <sub>H</sub>  | High input level     | -                      | 2.3       | -   | VDD5 +0.3 | V    |
|     | V <sub>HYST</sub> | Hysteresis           | -                      | 0.1       | -   | -         | V    |
|     | I <sub>IN</sub>   | Input current        | -                      | -         | -   | 5         | µA   |
| DO  | VDO <sub>L</sub>  | DO output low level  | Isink current = 2 mA   | -         | -   | 0.5       | V    |
|     | VDO <sub>H</sub>  | DO output high level | Isource current = 2 mA | VDD5 -0.5 | -   | -         | V    |
| CS  | EN <sub>L</sub>   | Low input level      | -                      | -0.3      | -   | 1.1       | V    |
|     | EN <sub>H</sub>   | High input level     | -                      | 2.3       | -   | VDD5 +0.3 | V    |
|     | V <sub>HYST</sub> | Hysteresis           | -                      | 0.1       | -   | -         | V    |
|     | I <sub>IN</sub>   | Input current        | -                      | -         | -   | 5         | µA   |
|     | R <sub>PU</sub>   | Pull up resistor     | -                      | 50        | -   | 250       | kΩ   |

**6.16.3 SPI registers**

**Table 55. SPI registers**

| Register                 | R/W | Address | Description             |
|--------------------------|-----|---------|-------------------------|
| CONFIG_REG1              | W   | 0x01    | Configuration registers |
| CONFIG_REG2              | W   | 0x02    |                         |
| CONFIG_REG3              | W   | 0x03    |                         |
| CONFIG_REG4              | W   | 0x04    |                         |
| CONFIG_REG5              | W   | 0x05    |                         |
| CONFIG_REG6              | W   | 0x06    |                         |
| CONFIG_REG7              | W   | 0x07    |                         |
| CONFIG_REG9/SPI RESPTIME | W   | 0x11    |                         |
| CONFIG_REG10/CPS         | W   | 0x12    |                         |

Table 55. SPI registers (continued)

| Register   | R/W | Address   | Description  |
|--|-----|-----------|--|
| LOCK_UNLOCK_SW_RST   | W   | 0x0C      | Disable writing of all configuration bits/ software reset for the device     |
| START_REACT  | W   | 0x0D      | Enable power stages/MRD reactivate   |
| WD_ANSW/WDA RESP<br>CONFIG_REG8                            | W   | 0x0E      | Communicate the WD appropriate answer to WD query/U1A9 WDA Response to query |
| CONTR_REG1   | W   | 0x08      | Control register to switch on/off the OUT                                    |
| CONTR_REG2   | W   | 0x09      |  |
| CONTR_REG3   | W   | 0x0A      |  |
| CONTR_REG4   | W   | 0x0B      |  |
| <b>Following Registers have 0x10+subaddress SPI format</b> |     |           |  |
| IDENT_REG  | R   | 0x10+0x00 | Identifier (000)   |
| DIA_REG1   | R   | 0x10+0x01 | Diagnosis information of device  |
| DIA_REG2   | R   | 0x10+0x02 |  |
| DIA_REG3   | R   | 0x10+0x03 |  |
| DIA_REG4   | R   | 0x10+0x04 |  |
| DIA_REG5   | R   | 0x10+0x05 |  |
| DIA_REG6   | R   | 0x10+0x06 |  |
| DIA_REG7   | R   | 0x10+0x07 |  |
| DIA_REG8   | R   | 0x10+0x08 |  |
| DIA_REG9   | R   | 0x10+0x09 |  |
| DIA_REG10  | R   | 0x10+0x0A |  |
| DIA_REG11  | R   | 0x10+0x0B |  |
| DIA_REG12  | R   | 0x10+0x0C | Diagnostic register 12   |
| DIA_REG13  | R   | 0x10+0x0D | WDA RESPTIME   |
| DIA_REG14  | R   | 0x10+0x0E | WDA REQULO   |
| DIA_REG15  | R   | 0x10+0x0F | WDA REQUHI   |
| DIA_REG16  | R   | 0x10+0x10 | WDA RST_AB1_CNT  |

**Command register**

**Table 56. CLOCK\_UNLOCK\_SW\_RST**

| Bit | DIN        | DO         |
|-----|------------|------------|
| 15  | X          | SPI ERROR  |
| 14  | ADD(4)     | ADD(4)     |
| 13  | ADD(3)     | ADD(3)     |
| 12  | ADD(2)     | ADD(2)     |
| 11  | ADD(1)     | ADD(1)     |
| 10  | ADD(0)     | ADD(0)     |
| 9   | X          | 0          |
| 8   | X          | 0          |
| 7   | X          | 0          |
| 6   | X          | 0          |
| 5   | X          | 0          |
| 4   | X          | 0          |
| 3   | X          | 0          |
| 2   | SW_RESET   | 0          |
| 1   | LOCK       | LOCK       |
| 0   | Odd Parity | Odd Parity |

This command disables (“lock”) writing of all configuration registers. The commands have no relevant data as command data bit – they may be set to ‘1’ or ‘0’.

Default state is configuration registers not locked.

The content of lockable bit is valid both if the bits are locked or if they are unlocked. Writing data to the bit is possible if the bits are unlocked; the new values become valid during the execution of the write command.

This command generates a L9779WD-SPI internal reset initiated by the µC’s software (“software reset”) that clears all the configuration and diagnostic registers and switch-off all the drivers.

The command has no relevant data as command data bit – they may be set to ‘1’ or ‘0’.

**Table 57. START\_REACT**

| Bit | DIN    | DO        |
|-----|--------|-----------|
| 15  | X      | SPI ERROR |
| 14  | ADD(4) | ADD(4)    |
| 13  | ADD(3) | ADD(3)    |
| 12  | ADD(2) | ADD(2)    |
| 11  | ADD(1) | ADD(1)    |



Table 57. START\_REACT (continued)

| Bit | DIN        | DO         |
|-----|------------|------------|
| 10  | ADD(0)     | ADD(0)     |
| 9   | X          | 0          |
| 8   | X          | 0          |
| 7   | X          | 0          |
| 6   | X          | 0          |
| 5   | X          | 0          |
| 4   | X          | 0          |
| 3   | STOP       | 0          |
| 2   | START      | 0          |
| 1   | MRD_REACT  | OUT_DIS    |
| 0   | Odd Parity | Odd Parity |

The command START sets the bit <OUT\_DIS> to '0'. With <OUT\_DIS> = '0' the outputs [OUT1...OUT10] [OUT13...OUT28] and [IGN1...IGN4] can be activated using control registers. After a reset (default state) the bit is <OUT\_DIS>='1' and the outputs are disabled (so any SPI data frame writing control registers is ignored and the power stages are all switched off).

The command has no relevant data as command data bit – they may be set to '1' or '0'.

This command allows the  $\mu$ C turning on the MRD if it is switched off due to over current.

Configuration registers

CONFIG\_REG1

Configuration register 1

|          |   |   |   |   |   |          |            |
|----------|---|---|---|---|---|----------|------------|
| 7        | 6 | 5 | 4 | 3 | 2 | 1        | 0          |
| RESERVED |   |   |   |   |   | VRS mode | MRD_OT_DID |
| -        |   |   |   |   |   | W        | W          |

**Address:** 0 0001  
**Type:** W (write access: WRITE\_CONFIG1)  
**Reset:** 0000 1000  
 [7:5] RESERVED  
 [4:2] RESERVED  
 [1] VRS mode:  
 0 = limited adaptive (default)  
 1 = full adaptive  
 [0] MRD\_OT\_DIS: Disables OT switch\_off for MRD:  
 0 = MRD OT switches off the driver  
 1 = MRD OT does NOT switch off the driver

CONFIG\_REG2

Configuration register 2

|          |   |   |   |   |   |                 |            |
|----------|---|---|---|---|---|-----------------|------------|
| 7        | 6 | 5 | 4 | 3 | 2 | 1               | 0          |
| RESERVED |   |   |   |   |   | Charge pump OFF | LS_IGN_OFF |
| -        |   |   |   |   |   | W               | W          |

**Address:** 0 0010  
**Type:** W (write access: WRITE\_CONFIG2)  
**Reset:** 0000 1000  
 [7:5] RESERVED  
 [4:2] RESERVED  
 [1] Charge pump OFF  
 0= ON (default)  
 1= OFF  
 [0] LS\_IGN\_OFF Control LS stage of IGN driver  
 0 = normal behaviour  
 1 = LS of IGN driver always OFF

**CONFIG\_REG3****Configuration register 3**

|          |   |   |   |   |   |                 |            |
|----------|---|---|---|---|---|-----------------|------------|
| 7        | 6 | 5 | 4 | 3 | 2 | 1               | 0          |
| RESERVED |   |   |   |   |   | EN_FALLING_FILT | HYS_FB_SEL |
| -        |   |   |   |   |   | W               |            |

**Address:** 0 0011

**Type:** W (write access: WRITE\_CONFIG3)

**Reset:** 0000 1000

[7:5] RESERVED

[4:2] RESERVED

[1] EN\_FALLING\_FILT:

0 = Falling edge filter disabled

1 = Falling edge filter enabled

[0] HYS\_FB\_SEL:

0 = VRS hyst. Feedback connected before adaptative filter

1 = VRS hyst. Feedback connected after adaptative filter

**CONFIG\_REG4**

**Configuration register 4**

|                       |   |   |          |          |   |         |      |
|-----------------------|---|---|----------|----------|---|---------|------|
| 7                     | 6 | 5 | 4        | 3        | 2 | 1       | 0    |
| PWL_TIMEOUT_CONF[2:0] |   |   | OFF_LCDR | RESERVED |   | ISO_SRC | LOCK |
| W                     |   |   |          | -        |   | W       |      |

**Address:** 0 0100

**Type:** W (write access: WRITE\_CONFIG4)

**Reset:** 0000\_0010

[7:5] PWL\_TIMEOUT\_CONF[2:0]: Power latch mode time-out configuration.

- 000: Disabled (default)
- 001: 4.7 minutes ±5%
- 010: 9 minutes ±5%
- 011: 19 minutes ±5%
- 100: 28 minutes ±5%
- 101: 37 minutes ±5%
- 110: 75 minutes ±5%
- 111: 470 ms ±5%

[4] OFF\_LCDR: Off state diagnosis for Low-current drive  
 1 = Off state diagnosis and the bias current of OUT20 is active  
 0 = Off state diagnosis and the bias current of OUT20 is disabled

[3:2] RESERVED

[1] ISO\_SRC: Slew-rate control for the ISO9141 serial interface (K-Line)  
 0 = No slew rate limitation  
 1 = Slew-rate limitation active

[0] LOCK: Lock bit status. Set by LOCK command and cleared with UNLOCK command  
 1 = ALL configuration registers are locked and cannot be changed  
 0 = all configuration registers can be changed



## CONFIG\_REG5

## Configuration register 5

| 7        | 6        | 5        | 4         | 3         | 2         | 1         | 0         |
|----------|----------|----------|-----------|-----------|-----------|-----------|-----------|
| RESERVED | RESERVED | VRS_DIAG | VRS_MODE1 | VRS_MODE0 | VRS_HYST2 | VRS_HYST1 | VRS_HYST0 |
| -        | -        | W        |           |           |           |           |           |

**Address:** 0 0101

**Type:** W (write access: WRITE\_CONFIG5)

**Reset:** 1101\_1000

[7:6] RESERVED: not used

[5] If fully adaptive mode selected:

VRS diag: VRS diagnosis enable

1: diagnosis function is enabled

0: diagnosis function is disabled

If limited adaptive mode selected:

Forces VRS minimum hysteresis ( $5 \hat{I}/4A$ )

1: minimum hysteresis forced

0: normal operation as per VRS\_HYST configuration

[4:3] VRS\_MODE

00: Internal auto-adaptive hysteresis OFF, internal auto-adaptive filter time OFF

01: Internal auto-adaptive hysteresis ON, internal auto-adaptive filter time OFF

10: Internal auto-adaptive hysteresis OFF, internal auto-adaptive filter time ON

11: Internal auto-adaptive hysteresis ON, internal auto-adaptive filter time ON

[2:0] VRS\_HYST

000: Hys current = 17  $\mu$ A (Hys VRS = 347 mV with 10 k $\Omega$  ext resistors) [default]

001: Hys current = 5  $\mu$ A (Hys VRS=100mV with 10 k $\Omega$  ext resistors)

010: Hys current = 10  $\mu$ A (Hys VRS=200mV with 10 k $\Omega$  ext resistors)

011: Hys current = 17  $\mu$ A (Hys VRS=347mV with 10 k $\Omega$  ext resistors)

100: Hys current = 32  $\mu$ A (Hys VRS=644mV with 10 k $\Omega$  ext resistors)

101: Hys current = 51  $\mu$ A (Hys VRS=967mV with 10 k $\Omega$  ext resistors)

110: Hys current = 17  $\mu$ A (Hys VRS=347mV with 10 k $\Omega$  ext resistors)

111: Hys current = 0  $\mu$ A (used only for test purpose)

**Note:** When VRS limited amplitude adaptive mode is set, VRS\_HYST limits the minimum hysteresis to the set value.

When VRS limited mode is set, filter time must be enabled at operation start, and shall never be disabled afterwards.

When VRS limited mode is set, VRS diagnostic function is not available.

**CONFIG\_REG6**

**Configuration register 6**

|            |        |                       |       |                     |                     |  |                    |
|------------|--------|-----------------------|-------|---------------------|---------------------|--|--------------------|
| 7          | 6      | 5                     | 4     | 3                   | 2                   | 1                                      | 0                  |
| CAN_ERR_EN | NL_RST | PWL_EN_N/<br>SEO_EN_N | PSOFF | VDD5_UV RST<br>mask | VDD5_UV WDA<br>mask | WDA time base<br>setting<br>(RESPTIME) | PWL/SEO<br>timeout |
| W          |        |                       |       |                     |                     |  |                    |

**Address:** 0 0110

**Type:** W (write access: WRITE\_CONFIG6)

**Reset:** 0010 0010

- [7] CAN\_ERR\_EN: CAN error handling  
1: CAN error handling enabled  
0: CAN error handling disabled
- [6] NL\_RST: Reset generation during Power latch mode when KEY\_ON 0 --> 1  
1: reset generated  
0: reset not generated
- [5] PWL\_EN\_N: Power latch mode enable  
PWL\_EN\_N/SEO\_EN\_N: Power latch/secure engine off mode enable  
1: power latch mode function is disabled (default)  
0: power latch mode function is enabled
- [4] PSOFF: Power supply off (VDD5, VTRK1, VTRK2, Charge-pump, internal supply) when KEY\_ON = 0 and PWL\_EN\_N = 0  
0: switch off power supply and switch off MRD  
1: do not switch off power supply and switch off MRD
- [3] VDD5\_UV RST mask  
1: mask VDD5\_UV with generating RST event  
0: mask removed (default), VDD5\_UV event generates RST
- [2] VDD5\_UV WDA mask  
1: mask VDD5\_UV with generating WDA event  
0: mask removed (default). Any VDD5\_UV event pulls WDA pin low and disables safety drivers
- [1] WDA time base setting  
This bit selects the RESPTIME time base  
1: (default) sets time base to 1/64 kHz  
0: sets time base to 1/39 kHz
- [0] PWL/SEO timeout  
0: PWL timeout counter has priority over SEO (default)  
1: SEO timeout counter has priority over PW

## CONFIG\_REG7

## Configuration register 7

|              |              |            |                       |               |               |             |             |
|--------------|--------------|------------|-----------------------|---------------|---------------|-------------|-------------|
| 7            | 6            | 5          | 4                     | 3             | 2             | 1           | 0           |
| IGN_DIA_MODE | IGN_DIA_SGEN | TD_MASK_X2 | CPS/Stepper<br>Unlock | OUTC_HS_EN_LB | OUTA_HS_EN_LB | OUT14_EN_LB | OUT13_EN_LB |
| W            |              |            |                       |               |               |             |             |

**Address:** 0 0111

**Type:** W (write access: WRITE\_CONFIG7)

**Reset:** 0101 0000

- [7] IGN\_DIA\_MODE: IGN diagnosis mode for short to battery:  
1: latch mode  
0: no latch mode
- [6] IGN\_DIA\_SGEN: IGN diagnosis enable for short to ground:  
1: Current diagnosis enabled  
0: Voltage diagnosis disabled
- [5] TD\_MASK\_X2:  
0: Td\_mask as specified in respective tables for OUT13 to OUT28  
1: Td\_mask doubled for OUT13 to OUT28
- [4] CPS/Stepper Unlock bit:  
1: Stepper mode selected (default)  
0: CPS mode selected
- [3] OUTC\_HS\_EN\_LB: Low battery function enable  
1: LB function is enabled for OUTC\_HS  
0: LB function is disabled for OUTC\_HS
- [2] OUTA\_HS\_EN\_LB: Low battery function enable  
1: LB function is enabled for OUTA\_HS  
0: LB function is disabled for OUTA\_HS
- [1] OUT14\_EN\_LB: Low battery function enable  
1: LB function is enabled for OUT14  
0: LB function is disabled for OUT14
- [0] OUT13\_EN\_LB: Low battery function enable  
1: LB function is enabled for OUT13  
0: LB function is disabled for OUT13

*Note: The bit OUTA\_HS, OUTC\_HS\_EN\_LB has priority over the CPS\_CONFx bit, this means that if one of OUT21,25\_EN\_LB is set to 1 the OUT21...28 become independent power stages.*

**WD\_ANSW/WDA RESP/CONFIG\_REG8****Configuration register 8**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
| RESP | RESP | RESP | RESP | RESP | RESP | RESP | RESP |
| W    |      |      |      |      |      |      |      |

**Address:** 0 1110**Type:** W**Reset:** -

[7:0] RESP: the answer of the  $\mu$ C to the monitoring module question of the U-Chip - to the U-Chip-internal logic of the monitoring module.

**CONFIG\_REG9/SPI RESPTIME****Configuration register 9**

|          |         |          |          |          |          |          |          |
|----------|---------|----------|----------|----------|----------|----------|----------|
| 7        | 6       | 5        | 4        | 3        | 2        | 1        | 0        |
| INIT_WDR | CAN_TDI | RESPTIME | RESPTIME | RESPTIME | RESPTIME | RESPTIME | RESPTIME |
| W        |         |          |          |          |          |          |          |

**Address:** 1 0001**Type:** W**Reset:** -

[7] IINIT\_WDR (enable WDA reset)

[6] CAN\_TDI (disable CAN in case of WDA event)

[5:0] RESPTIME of the monitoring module



**CONFIG\_REG10 (CPS Configuration register)**

**Configuration register 10**

|                              |   |   |   |   |   |   |          |
|------------------------------|---|---|---|---|---|---|----------|
| 7                            | 6 | 5 | 4 | 3 | 2 | 1 | 0        |
| see <a href="#">Table 37</a> |   |   |   |   |   |   | CPS_CONF |
| W                            |   |   |   |   |   |   |          |

**Address:** 1 0010  
**Type:** WR\_CPS  
**Reset:** -

[7:1] See [Table 37](#)

- [0] CPS\_CONF (CPS mode is enabled if REG7 bit4 is cleared first)
- 1: OUTA...OUTD are configured as 2 full-bridge for stepper motor driving (default)
- 0: OUTA...OUTD are configured as half bridges

**IDENT\_REG/DIA\_REG[1:5]**

**Diagnostic register 1, 2, 3, 4, 5**

|          |            |   |            |   |            |   |            |   |
|----------|------------|---|------------|---|------------|---|------------|---|
|          | 7          | 6 | 5          | 4 | 3          | 2 | 1          | 0 |
| DIA_REG1 | OUT4_DIAG  |   | OUT3_DIAG  |   | OUT2_DIAG  |   | OUT1_DIAG  |   |
| DIA_REG2 | 0          | 0 | OUT7_DIAG  |   | OUT6_DIAG  |   | OUT5_DIAG  |   |
| DIA_REG3 | OUT14_DIAG |   | OUT13_DIAG |   | WDA_STATUS | 1 | 0          | 0 |
| DIA_REG4 | OUT18_DIAG |   | OUT17_DIAG |   | OUT16_DIAG |   | OUT15_DIAG |   |
| DIA_REG5 | RESERVED   |   |            |   | OUT20_DIAG |   | 0          | 0 |

**Address:** 1 0000  
**Subaddress:** 0000 0001,  
 0000 0010,  
 0000 0011,  
 0000 0100,  
 0000 0101  
**Type:** R (Read only)  
**Reset:** 0000 0000

- DIA\_REG1:[7:6] OUT4\_DIAG: Diagnosis bit of power stage OUT4
  - 00: Short-circuit to ground (SCG)
  - 01: Open load (OL)
  - 10: Short-circuit to BAT (SCB)
  - 11: Power stage OK NO FAIL
- DIA\_REG1:[5:4] OUT3\_DIAG: Diagnosis bit of power stage OUT3
  - 00: Short-circuit to ground (SCG)
  - 01: Open load (OL)
  - 10: Short-circuit to BAT (SCB)
  - 11: Power stage OK NO FAIL



- DIA\_REG1:[3:2] OUT2\_DIAG: Diagnosis bit of power stage OUT2  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG1:[1:0] OUT1\_DIAG: Diagnosis bit of power stage OUT1  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG2:[7:6] 00
- DIA\_REG2:[5:4] OUT7\_DIAG: Diagnosis bit of power stage OUT7  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG2:[3:2] OUT6\_DIAG: Diagnosis bit of power stage OUT6  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG2:[1:0] OUT5\_DIAG: Diagnosis bit of power stage OUT5  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG3:[7:6] OUT14\_DIAG: Diagnosis bit of power stage OUT14  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG3:[5:4] OUT13\_DIAG: Diagnosis bit of power stage OUT13  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL
- DIA\_REG3:[3] WDA STATUS: status of WDA pin, not latched
- DIA\_REG3:[2] RESERVED: not used
- DIA\_REG3:[1:0] 00
- DIA\_REG4:[7-6] OUT18\_DIAG: Diagnosis bit of power stage OUT18  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL

DIA\_REG4:[5-4] OUT17\_DIAG: Diagnosis bit of power stage OUT17  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL

DIA\_REG4:[3-2] OUT16\_DIAG: Diagnosis bit of power stage OUT16  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL

DIA\_REG4:[1-0] OUT15\_DIAG: Diagnosis bit of power stage OUT15  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL

DIA\_REG5:[7:4] RESERVED: All bit read 1

DIA\_REG5:[3-2] OUT20\_DIAG: Diagnosis bit of power stage OUT20  
00: Short-circuit to ground (SCG)  
01: Open load (OL)  
10: Short-circuit to BAT (SCB)  
11: Power stage OK NO FAIL

DIA\_REG5:[1-0] 00

*Note: All diagnosis bits (including OT1, F1, OT2, F2) will be cleared automatically by reading – i.e. if a diagnosis bit indicates a fault this fault has occurred after the last read access to this register.*

Diagnostic register 6 and 7

DIA\_REG6

Diagnostic register 6

|                                      |            |   |            |   |            |   |            |   |
|--------------------------------------|------------|---|------------|---|------------|---|------------|---|
|                                      | 7          | 6 | 5          | 4 | 3          | 2 | 1          | 0 |
| Configured as<br>single power stages | OUT24_DIAG |   | OUT23_DIAG |   | OUT22_DIAG |   | OUT21_DIAG |   |
| Configured as H bridge               | H1_DIAG    |   |            |   |            |   |            |   |

**Address:** 1 0000  
**Subaddress:** 0000 0110  
**Type:** R (Read only)  
**Reset:** 0000 0000

**Configured as single power stages**

- [7-6] OUT24\_diag[1:0]: Diagnosis bit of OUT24  
 00: Short-circuit to ground  
 01: Open load (OL)  
 10: Short-circuit to BAT (SCB)  
 11: Power stage OK NO FAIL
- [5-4] OUT23\_diag[1:0]: Diagnosis bit of OUT23  
 00: Short-circuit to VB  
 01: Open load (OL)  
 10: Short-circuit to GND  
 11: Power stage OK NO FAIL
- [3-2] OUT22\_diag[1:0]: Diagnosis bit of OUT22  
 00: Short-circuit to ground  
 01: Open load (OL)  
 10: Short-circuit to BAT (SCB)  
 11: Power stage OK NO FAIL
- [1-0] OUT21\_diag[1:0]: Diagnosis bit of OUT21  
 00: Short-circuit to VB  
 01: Open load (OL)  
 10: Short-circuit to GND  
 11: Power stage OK NO FAIL

**Configured as H bridge**

- [7-0] H1\_diag[7:0]: Diagnosis bit of H1 bridge  
 00000001: Short to Ground (OFF)  
 00000101: Short to VBAT (OFF)  
 00000100: Open Load (OFF)  
 00000010: Open Load (ON)  
 00000011: Over current (ON)  
 00000111: Fault detection running (ON)  
 11111111: Power stages OK NO FAULT  
 All other combinations: NOT USED

**DIA\_REG7**

**Diagnostic register 7**

|                                      |            |   |            |   |            |   |            |   |
|--------------------------------------|------------|---|------------|---|------------|---|------------|---|
|                                      | 7          | 6 | 5          | 4 | 3          | 2 | 1          | 0 |
| Configured as<br>single power stages | OUT28_DIAG |   | OUT27_DIAG |   | OUT26_DIAG |   | OUT25_DIAG |   |
| Configured as<br>H bridge            | H2_DIAG    |   |            |   |            |   |            |   |

**Address:** 1 0000  
**Subaddress:** 0000 0111  
**Type:** R (Read only)  
**Reset:** 0000 0000

**Configured as single power stages**

- [7-6] OUT28\_DIAG[1:0]: Diagnosis bit of OUT28  
 00: Short-circuit to ground  
 01: Open load (OL)  
 10: Short-circuit to BAT (SCB)  
 11: Power stage OK NO FAIL
- [5-4] OUT27\_DIAG[1:0]: Diagnosis bit of OUT27  
 00: Short-circuit to ground  
 01: Open load (OL)  
 10: Short-circuit to BAT (SCB)  
 11: Power stage OK NO FAIL
- [3-2] OUT26\_DIAG[1:0]: Diagnosis bit of OUT26  
 00: Short-circuit to VB  
 01: Open load (OL)  
 10: Short-circuit to GND  
 11: Power stage OK NO FAIL
- [1-0] OUT25\_DIAG[1:0]: Diagnosis bit of OUT25  
 00: Short-circuit to VB  
 01: Open load (OL)  
 10: Short-circuit to GND  
 11: Power stage OK NO FAIL

**Configured as H bridge**

- [7-0] H2\_diag[7:0]: Diagnosis bit of H2 bridge  
 00000001: Short to Ground (OFF)  
 00000101: Short to VBAT (OFF)  
 00000100: Open Load (OFF)  
 00000010: Open Load (ON)  
 00000011: Over current (ON)  
 00000111: Fault detection running (ON)  
 11111111: Power stages OK NO FAULT  
 All other combinations: NOT USED

**DIA\_REG8**

**Diagnostic register 8**

|                |   |                |   |                |   |                |   |
|----------------|---|----------------|---|----------------|---|----------------|---|
| 7              | 6 | 5              | 4 | 3              | 2 | 1              | 0 |
| IGN4_DIAG[1:0] |   | IGN3_DIAG[1:0] |   | IGN2_DIAG[1:0] |   | IGN1_DIAG[1:0] |   |
|                |   |                |   |                |   |                |   |

**Address:** 1 0000

**Subaddress:** 0000 1000

**Type:** R (Read only)

**Reset:** 0000 0000

- [7:6] IGN4\_DIAG[1:0]: Diagnosis bit of IGN4
  - 00: Short-circuit to ground (SCG)
  - 01: Open load (OL)
  - 10: Short-circuit to BAT (SCB)
  - 11: Power stage ok NO FAIL
- [5:4] IGN3\_DIAG[1:0]: Diagnosis bit of IGN3
  - 00: Short-circuit to ground (SCG)
  - 01: Open load (OL)
  - 10: Short-circuit to BAT (SCB)
  - 11: Power stage ok NO FAIL
- [3:2] IGN2\_DIAG[1:0]: Diagnosis bit of IGN2
  - 00: Short-circuit to ground (SCG)
  - 01: Open load (OL)
  - 10: Short-circuit to BAT (SCB)
  - 11: Power stage ok NO FAIL
- [1:0] IGN1\_DIAG[1:0]: Diagnosis bit of IGN1
  - 00: Short-circuit to ground (SCG)
  - 01: Open load (OL)
  - 10: Short-circuit to BAT (SCB)
  - 11: Power stage ok NO FAIL

**DIA\_REG9**

**Diagnostic register 9**

|               |         |          |          |                 |   |                 |   |
|---------------|---------|----------|----------|-----------------|---|-----------------|---|
| 7             | 6       | 5        | 4        | 3               | 2 | 1               | 0 |
| KEY_ON_STATUS | MRD_OVC | VRS_STAT | VRS_DIAG | VTRK2_DIAG[1:0] |   | VTRK1_DIAG[1:0] |   |
| R/W           |         |          |          |                 |   |                 |   |

**Address:** 1 0000

**Subaddress:** 0000 1001

**Type:** R (Read only)

**Reset:** 0000 0000

- [7] KEY\_ON\_STATUS
  - 1: KEY\_ON voltage above KEY\_ON\_H
  - 0: KEY\_ON voltage below KEY\_ON\_L
- [6] MRD\_OVC
  - 1: Current MRD status is OFF due to previous Over current
  - 0: Current MRD status is ON (no OVC detected)
- [5] VRS\_STAT
  - 1: Diag ON
  - 0: Diag OFF
- [4] VRS\_DIAG
  - 0: No Fault
  - 1: Generic fault detected
- [3-2] VTRK2\_DIAG[1:0]: Diagnosis bit of VTRK2
  - 00: Not used
  - 01: Overload condition/out of regulation
  - 10: Overvoltage (OV) or over temperature (OT) (Lower priority respect to Overload condition)
  - 11: Sensor supply VTRK ok NO FAIL
- [1-0] VTRK1\_DIAG[1:0]: Diagnosis bit of VTRK1
  - 00: Not used
  - 01: Overload condition/out of regulation
  - 10: Overvoltage (OV) or over temperature (OT) (Lower priority respect to overload condition)
  - 11: Sensor supply VTRK OK NO FAIL

**DIA\_REG10**

**Diagnostic register 10**

|         |    |         |    |         |         |         |        |
|---------|----|---------|----|---------|---------|---------|--------|
| 7       | 6  | 5       | 4  | 3       | 2       | 1       | 0      |
| TNL_RST | F1 | CRK_RST | F2 | VDD5_OV | V3V3_UV | OUT_DIS | OV_RST |
|         |    |         |    |         |         |         |        |

**Address:** 1 0000

**Subaddress:** 0000 1010

**Type:** R (Read only)

**Reset:** 0000 0000

- [7] TNL\_RST  
0: No reset generated  
1: Reset generated by TNL
- [6] F1  
0: No fault  
1: any fault occurred in OUT1...10, OUT13...20, IGN1...4
- [5] CRK\_RST  
0: No reset generated  
1: Reset generated by VDD\_UV (t<THOLD)
- [4] F2  
0: No fault  
1: any fault occurred in OUT21...28
- [3] VDD5\_OV  
0: No fault  
1: Overvoltage on VDD5 regulator
- [2] V3V3\_UV  
0: No fault  
1: Undervoltage on V3V3 regulator
- [1] OUT\_DIS  
0: All OUT can be switched ON  
1: All OUT disabled (except MRD and supplies)
- [0] OV\_RST  
0: No fault  
1: Power stages were switched off due to battery overvoltage

*Note: <OUT\_DIS>: this bit has to be set to 0 with the command START before power stages OUTx and IGNx can be activated. As long as <OUT\_DIS>=1 any data for these power stages are ignored. It is not affected by reading, and it is reset by POR, software reset SW\_RST command and when the RST pin is asserted.*



**DIA\_REG11**

**Diagnostic register 11**

|     |     |     |     |            |           |                  |   |
|-----|-----|-----|-----|------------|-----------|------------------|---|
| 7   | 6   | 5   | 4   | 3          | 2         | 1                | 0 |
| OT1 | OT2 | OT3 | OT4 | VDD5UV_RST | CAN_ERROR | WD_FAULT_LATCHED | 0 |
|     |     |     |     |            |           |                  |   |

**Address:** 1 0000

**Subaddress:** 0000 1011

**Type:** R (Read only)

**Reset:** 0000 0000

- [7] OT1  
0: No fault  
1: Over temperature occurred in VTRK1,2
- [6] OT2  
0: No fault  
1: Over temperature occurred in the OUTx and IGNx
- [5] OT3  
0: No fault  
1: Over temperature occurred in MRD
- [4] OT4  
0: No fault  
1: Over temperature occurred in V3V3
- [3] VDD5UV\_RST  
0: No reset generated  
1: Reset generated by VDD\_UV (t>THOLD)
- [2] CAN\_ERROR  
0: No fault  
1: fault present (one of the 4 possible error on CAN)
- [1] WD\_FAULT\_LATCHED  
1: WDA has generated a RST event  
0: no event
- [0] 0

**DIA\_REG12**

**Diagnostic register 12**

|          |                  |            |             |          |          |   |            |
|----------|------------------|------------|-------------|----------|----------|---|------------|
| 7        | 6                | 5          | 4           | 3        | 2        | 1 | 0          |
| RESERVED | WD_FAULT_LATCHED | SEO OUT1-4 | SEO OUT1314 | WD_FAULT | RESERVED |   | KEY_ON_FLT |
|          |                  |            |             |          |          |   |            |

**Address:** 1 0000

**Subaddress:** 0000 1100

**Type:** R (Read only)

**Reset:** 0000 0000

[7] RESERVED

[6] WDA\_FAULT latched:  
 1: WDA has generated a RST event  
 0: no event

[5] SEO event when the OUT1-4 are switched off after 225 ms

[4] SEO event when the OUT13-14 after 600ms when KEY is OFF

[3] WDA\_FAULT not latched:  
 1: WDA has generated a RST event (the DIA\_REG12 is read by READ\_DATA 7 but the bit WD\_FAULT\_LATCHED is reset by READ\_DATA5).  
 0: no event

[2:1] RESERVED: not used

[0] KEY\_ON\_FLT: Key on after filter

**Watchdog related SPI registers**

SPI registers WDA\_RESPTIME,REQULO, REQUHI, RST\_AB1\_CNT are defined as here below:

**DIA\_REG13/WDA\_RESPTIME****Diagnostic register 13**

|   |   |           |           |           |           |           |           |
|---|---|-----------|-----------|-----------|-----------|-----------|-----------|
| 7 | 6 | 5         | 4         | 3         | 2         | 1         | 0         |
| 0 | 0 | RESPTIME5 | RESPTIME4 | RESPTIME3 | RESPTIME2 | RESPTIME1 | RESPTIME0 |
| R |   |           |           |           |           |           |           |

**Address:** 1 0000

**Subaddress:** 0000 1101

**Type:** R (Read only)

**Reset:** 0011 1111b (reset source: Bit 5-0: RST\_UV, RST\_PRL; Bit 6-7: RST\_UV)

[7] 0

[6] 0

[5-0] RESPTIME (5-0): Response-time =  $(1 + 101 \cdot \text{RESPTIME}(5-0)) \cdot 1/f_{\text{clk}}$  with  $f_{\text{clk}} = 64\text{kHz}$

The error counter is incremented by one on a controller write access to this register!  
not locked by command LOCK

<RESPTIME(5..0)> may be written by the command WR\_RESPTIME

**DIA\_REG14/REQULO****Diagnostic register 14**

|         |          |          |          |       |       |       |       |
|---------|----------|----------|----------|-------|-------|-------|-------|
| 7       | 6        | 5        | 4        | 3     | 2     | 1     | 0     |
| WDA_INT | ERR_CNT2 | ERR_CNT1 | ERR_CNT0 | REQU3 | REQU2 | REQU1 | REQU0 |
| R       |          |          |          |       |       |       |       |

**Address:** 1 0000

**Subaddress:** 0000 1110

**Type:** R (Read only)

**Reset:** 1110 0000b (reset source: Bit 6-4: RST\_UV, RST\_PRL; Bit 7, 3-0: RST\_UV)

[7] WDA\_INT: '1': ERROR COUNTER > 4

[6-4] ERR\_CNT (2-0): value of the ERROR COUNTER

[3-0] REQU (3-0): 4-bit question

DIA\_REG15/REQUHI

Diagnostic register 15

|           |           |          |         |      |        |         |               |
|-----------|-----------|----------|---------|------|--------|---------|---------------|
| 7         | 6         | 5        | 4       | 3    | 2      | 1       | 0             |
| RESP_CNT1 | RESP_CNT0 | RESP_ERR | RESP_Z0 | CHRT | W_RESP | NO_RESP | RESP_TO_EARLY |
| R         |           |          |         |      |        |         |               |

**Address:** 1 0000

**Subaddress:** 0000 1111

**Type:** R (Read only)

**Reset:** 1100 0000b (reset source: RST\_UV, Bit 4 additionally RST\_PRL)

- [7-6] RESP\_CNT(1-0):  
'1': Response before time window was opened; reset to zero at sequencer-run<sup>(1)</sup>
- [5] RESP\_ERR:  
'1': 1 byte of the 32-bit response is incorrect<sup>(1)</sup>
- [4] RESP\_Z0:  
'1': Controller set response-time to 0ms; a correct response within the time window nevertheless increments the error counter by one '0': Response-time is greater than 0ms
- [3] CHRT:  
'1': Controller has changed response-time; reset to zero after a read access and after the next sequencer run
- [2] W\_RESP:  
'1': incorrect response in value; reset to zero at sequencer-run <sup>(1)</sup>
- [1] NO\_RESP:  
'1': no response; timer is restarted automatically; reset to zero after a read access
- [0] RESP\_TO\_EARLY:  
'1': Response before time window was opened; reset to zero at sequencer-run <sup>(1)</sup>

1. Sequencer-run: A sequencer-run is initiated by the writing of a complete response (RESP\_BYTE3&#226;RESP\_BYTE0) or by writing of a response-time <RESPTIME> or by reaching the end of a time window. In case WDA reference time base (1/f\_clk) has to be changed to f\_clk = 39 kHz, CONFIG6 bit1 has to be written to 0 before sequencer-run is started.

RESP\_TO\_EARLY = '1':

monitoring module has received a response before beginning of the time window and therefore this was rejected. Reception of a response means "end of reception of RESP\_BYTE0" after the other response bytes (i.e. RESP\_BYTE3, RESP\_BYTE2, RESP\_BYTE1 - in this order!) have been received.

NO\_RESP = '1':

monitoring module has received no response at all or a response too late after the time window already closed. However, a response too late might be read as RESP\_TO\_EARLY, as a too late response is at the same time a too early response concerning the next WDG cycle. Which results in the NO\_RESP monitoring being overwritten by a RESP\_TO\_EARLY monitoring.

This means that no "end of reception of RESP\_BYTE0" was detected before the end of the time window - neither during the time window nor before beginning of the time window. (Remember: RESP\_BYTE0 is the last of four response bytes!)



W\_RESP = '1':

an error occurred during the sequencer run before.

RESP\_ERR = '1':

an error occurred during the actual sequencer run. The bit will be set to '1' after receiving any incorrect answer byte and will remain '1' until the end of the actual sequencer run (no matter if the other answer bytes in this sequencer run are correct or not).

At the end of a sequencer run the error bit W\_RESP will be set to the actual value of RESP\_ERR, and thereafter the error bit RESP\_ERR will be cleared to '0'.

RESP\_CNT = '11': waiting for RESP\_BYTE3

RESP\_CNT = '10': waiting for RESP\_BYTE2 (after RESP\_BYTE3 was received)

RESP\_CNT = '01': waiting for RESP\_BYTE1 (after RESP\_BYTE2 was received)

RESP\_CNT = '00': waiting for RESP\_BYTE0 (after RESP\_BYTE1 was received)

**DIAG\_REG16/RST\_AB1\_CNT**

**Diagnostic register 16**

|   |   |          |          |          |          |          |          |
|---|---|----------|----------|----------|----------|----------|----------|
| 7 | 6 | 5        | 4        | 3        | 2        | 1        | 0        |
| 0 | 0 | AB1_CNT2 | AB1_CNT1 | AB1_CNT0 | RST_CNT2 | RST_CNT1 | RST_CNT0 |
| R |   |          |          |          |          |          |          |

**Address:** 1 0000

**Subaddress:** 0001 0000

**Type:** R (Read only)

**Reset:** 0000 0000b (reset source: Bit 6...0: only RST\_UV; RST\_PRL has no effect)

[7] 0

[6] 0

[5-3] AB1\_CNT (2-0)

[2-0] RST\_CNT (2-0) reset counter RST\_CNT

**Control registers CONTR1 to 4**

They control the output stages OUT1...10, OUT13...20, OUT21...28 and IGNn.

CMD = 1 OUTPUT ON  
 CMD = 0 OUTPUT OFF

**CONTR\_REG1**

**Control register 1**

|          |          |          |          |          |           |          |          |
|----------|----------|----------|----------|----------|-----------|----------|----------|
| 7        | 6        | 5        | 4        | 3        | 2         | 1        | 0        |
| CMD_OUT1 | CMD_OUT2 | CMD_OUT3 | CMD_OUT4 | CMD_OUT5 | CMD_OUT20 | RESERVED | RESERVED |
| W        |          |          |          |          |           |          |          |

**Address:** 0 1000

**Type:** Via DATA frame

**Reset:** 0000 0000 (ALL outputs switched OFF)

- [7] CMD\_OUT1
  - 1: OUT1 - Power stage switched ON
  - 0: OUT1 - Power stage switched OFF
- [6] CMD\_OUT2
  - 1: OUT2 - Power stage switched ON
  - 0: OUT2 - Power stage switched OFF
- [5] CMD\_OUT3
  - 1: OUT3 - Power stage switched ON
  - 0: OUT3 - Power stage switched OFF
- [4] CMD\_OUT4
  - 1: OUT4 - Power stage switched ON
  - 0: OUT4 - Power stage switched OFF
- [3] CMD\_OUT5
  - 1: OUT5 - Power stage switched ON
  - 0: OUT5 - Power stage switched OFF
- [2] CMD\_OUT20
  - 1: OUT20 - Power stage switched ON
  - 0: OUT20 - Power stage switched OFF
- [1] RESERVED
- [0] RESERVED

**CONTR\_REG2****Control register 2**

| 7         | 6         | 5          | 4        | 3        | 2        | 1        | 0        |
|-----------|-----------|------------|----------|----------|----------|----------|----------|
| CMD_OUT15 | CMD_OUT14 | DON'T CARE | RESERVED | CMD_IGN1 | CMD_IGN2 | CMD_IGN3 | CMD_IGN4 |
|           |           |            |          |          |          |          |          |

**Address:** 0 1001

**Type:** Via DATA frame

**Reset:** 0000 0000 (ALL outputs switched OFF)

- [7] CMD\_OUT15
  - 1: OUT15 - Power stage switched ON
  - 0: OUT15 - Power stage switched OFF
- [6] CMD\_OUT14
  - 1: OUT14 - Power stage switched ON
  - 0: OUT14 - Power stage switched OFF
- [5] DON'T CARE
- [4] RESERVED
- [3] CMD\_IGN1
  - 1: IGN1 - Power stage switched ON
  - 0: IGN1 - Power stage switched OFF
- [2] CMD\_IGN2
  - 1: IGN2 - Power stage switched ON
  - 0: IGN2 - Power stage switched OFF
- [1] CMD\_IGN3
  - 1: IGN3 - Power stage switched ON
  - 0: IGN3 - Power stage switched OFF
- [0] CMD\_IGN4
  - 1: IGN4 - Power stage switched ON
  - 0: IGN4 - Power stage switched OFF

**CONTR\_REG3**

**Control register 3**

|              |           |           |           |           |           |           |          |          |
|--------------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|
|              | 7         | 6         | 5         | 4         | 3         | 2         | 1        | 0        |
| CPS_CONF = 0 | CMD_OUT22 | CMD_OUT21 | CMD_OUT16 | CMD_OUT13 | CMD_OUT17 | CMD_OUT18 | CMD_OUT7 | CMD_OUT6 |
| CPS_CONF = 1 | DIR       | ENABLE    |           |           |           |           |          |          |

**Address:** 0 1010

**Type:** Via DATA frame

**Reset:** 0000 0000 (ALL outputs switched OFF)

- 0 CMD\_OUT6
  - 1: OUT6 - Power stage switched ON
  - 0: OUT6 - Power stage switched OFF
- 1 CMD\_OUT7
  - 1: OUT7 - Power stage switched ON
  - 0: OUT7 - Power stage switched OFF
- 2 CMD\_OUT18
  - 1: OUT18 - Power stage switched ON
  - 0: OUT18 - Power stage switched OFF
- 3 CMD\_OUT17
  - 1: OUT17 - Power stage switched ON
  - 0: OUT17 - Power stage switched OFF
- 4 CMD\_OUT13
  - 1: OUT13 - Power stage switched ON
  - 0: OUT13 - Power stage switched OFF
- 5 CMD\_OUT16
  - 1: OUT16 - Power stage switched ON
  - 0: OUT16 - Power stage switched OFF
- 6 CMD\_OUT21
  - 1: OUT21 - Power stage switched ON (High side driver)
  - 0: OUT21 - Power stage switched OFF
  - Note: If CPS\_CONF=0 (single power stages configuration)*
  - ENABLE
  - 0: stepper motor driver disabled
  - 1: stepper motor driver enabled
  - Note: If CPS\_CONF=1 (stepper motor driving configuration)*
- 7 CMD\_OUT22
  - 1: OUT22 - Power stage switched ON
  - Note: If CPS\_CONF=0 (single power stages configuration)*
  - 0: OUT22 - Power stage switched OFF
  - DIR
  - 0: forward direction
  - 1: backward direction
  - Note: if CPS\_CONF=1 (stepper motor driving configuration)*

*Note: The meaning of some CONTR\_REG3 bit depends on the configuration of bit CPS\_CONF of CONF\_REG1.*



**CONTR\_REG4****Control register 4**

|              |          |   |           |           |           |           |           |           |
|--------------|----------|---|-----------|-----------|-----------|-----------|-----------|-----------|
|              | 7        | 6 | 5         | 4         | 3         | 2         | 1         | 0         |
| CPS_CONF = 0 | RESERVED |   | CMD_OUT28 | CMD_OUT27 | CMD_OUT26 | CMD_OUT25 | CMD_OUT24 | CMD_OUT23 |
| CPS_CONF = 1 | RESERVED |   |           |           |           |           |           | PWM       |

**Address:** 0 1011**Type:****Reset:** 0000 0000 (ALL outputs switched OFF)

[6-7] RESERVED: NOT used

[5] CMD\_OUT28

- 1: OUT28 Power stage switched ON
- 0: OUT28 Power stage switched OFF

[4] CMD\_OUT27

- 1: OUT27 Power stage switched ON
- 0: OUT27 Power stage switched OFF

[3] CMD\_OUT26

- 1: OUT26 - Power stage switched ON (High side driver)
- 0: OUT26 - Power stage switched OFF

[2] CMD\_OUT25

- 1: OUT25 - Power stage switched ON (High side driver)
- 0: OUT25 - Power stage switched OFF

[1] CMD\_OUT24

- 1: OUT24 - Power stage switched ON
- 0: OUT24 - Power stage switched OFF

[0] If CPS\_CONF=0 (single power stages configuration)

CMD\_OUT23

- 1: OUT23 Power stage switched ON
- 0: OUT23 Power stage switched OFF

if CPS\_CONF=1 (stepper motor driving configuration)

PWM

- 1 → 0: no step change in the driving sequence
- 0 → 1: step change in the driving sequence (next step applied)

*Note: The meaning of some CONTR\_REG4 bit depends on the configuration of bit CPS\_CONF of CONF\_REG1.*

# 7 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](http://www.st.com).

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## 7.1 HiQUAD-64 package information

Figure 74. HiQUAD-64 package outline

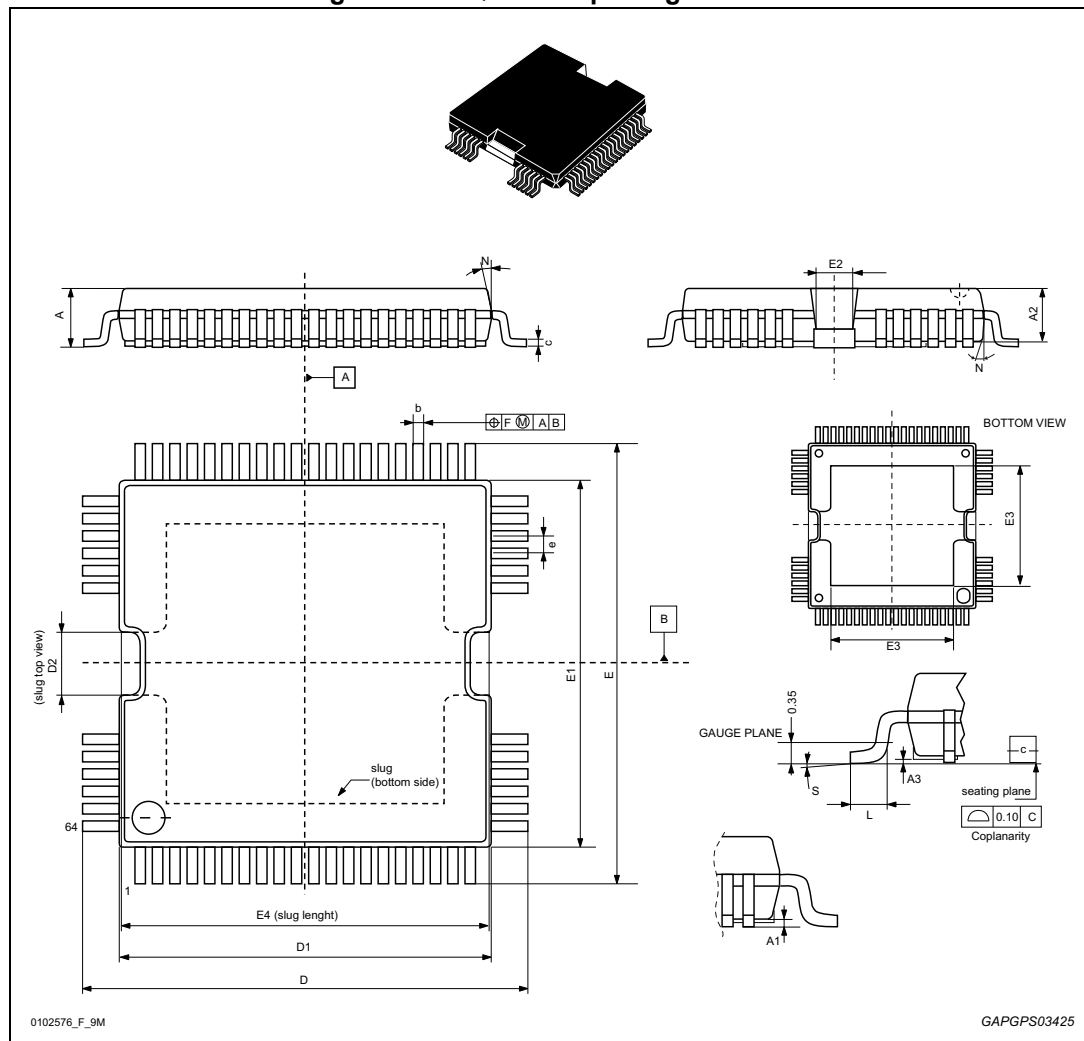


Table 58. HiQUAD-64 package mechanical data

| Ref               | Dimensions  |       |       |                       |        |        |
|-------------------|-------------|-------|-------|-----------------------|--------|--------|
|                   | Millimeters |       |       | Inches <sup>(1)</sup> |        |        |
|                   | Min.        | Typ.  | Max.  | Min.                  | Typ.   | Max.   |
| A                 | -           | -     | 3.15  | -                     | -      | 0.1240 |
| A1                | 0           | -     | 0.25  | 0                     | -      | 0.0098 |
| A2                | 2.50        | -     | 2.90  | 0.0984                | -      | 0.1142 |
| A3                | 0           | -     | 0.10  | 0                     | -      | 0.0039 |
| b                 | 0.22        | -     | 0.38  | 0.0087                | -      | 0.0150 |
| c                 | 0.23        | -     | 0.32  | 0.0091                | -      | 0.0126 |
| D <sup>(2)</sup>  | 17.00       | -     | 17.40 | 0.6693                | -      | 0.6850 |
| D1                | 13.90       | 14.00 | 14.10 | 0.5472                | 0.5512 | 0.5551 |
| D2                | 2.65        | 2.80  | 2.95  | 0.1043                | 0.1102 | 0.1161 |
| E                 | 17.00       | -     | 17.40 | 0.6693                | -      | 0.6850 |
| E1 <sup>(1)</sup> | 13.90       | 14.00 | 14.10 | 0.5472                | 0.5512 | 0.5551 |
| E2                | 2.35        | -     | 2.65  | 0.0925                | -      | 0.1043 |
| E3                | 9.30        | 9.50  | 9.70  | 0.3661                | 0.3740 | 0.3819 |
| E4                | 13.30       | 13.50 | 13.70 | 0.5236                | 0.5315 | 0.5394 |
| e                 | -           | 0.65  | -     | -                     | 0.0256 | -      |
| F                 | -           | 0.12  | -     | -                     | 0.0047 | -      |
| G                 | -           | 0.10  | -     | -                     | 0.0039 | -      |
| L                 | 0.80        | -     | 1.10  | 0.0315                | -      | 0.0433 |
| N                 | -           | -     | 10°   | -                     | -      | 10°    |
| s                 | 0°          | -     | 7°    | 0°                    | -      | 7°     |

1. Values in inches are converted from mm and rounded to 4 decimal digits.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.15mm (.006inc.).

## 8 Revision history

**Table 59. Document revision history**

| Date        | Revision | Changes  |
|-------------|----------|--|
| 08-Apr-2015 | 1        | Initial release.   |
| 08-May-2015 | 2        | Updated <a href="#">Table 30</a> , <a href="#">31</a> , <a href="#">32</a> and <a href="#">33</a> for the pins OUTA/B/C/D (High-side) the “Ron max” value is changed in 1.7 $\Omega$ . |

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