AN2751
Application note

L9952GXP power management system IC

Introduction

Today's industrial community and car makers in particular, recognize reduced fuel consumption and CO_2 emission as a competitive and differentiating advantage.

As a consequence, **innovative power management** solutions are mandatory in automotive embedded systems for solving the dilemma that consists in drastically reducing the overall quiescent current while the number of current sources is continuously increasing. In the meantime, the increasing systems complexity made necessary to integrate advanced **fail safe functionalities** in order to improve the sustainability and reliability of automotive electronic control units.

The **L9952GXP** power management system IC has been developed to fulfil both demands. It integrates all functions to build up a complete and **configurable supply** solution while providing comprehensive **fail safe functionality**.

The following product and application guide can be considered as a "**cookbook**" for designing L9952GXP power management based solutions. It is intended to help system, hardware and software developers to enhance, optimize and secure their applications.

This document will first introduce the key features and the main modes for operating a standard system. Advanced options and configurations will then be introduced for addressing more complex requirements. Finally the appendix will cover specific configuration scenarios and diagnostic procedures that need to be carefully handled in order to avoid any undesirable side effects. The L9952GXP software drivers have also been inserted in appendix for a faster and more effective handling of your system.

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List of abbreviations

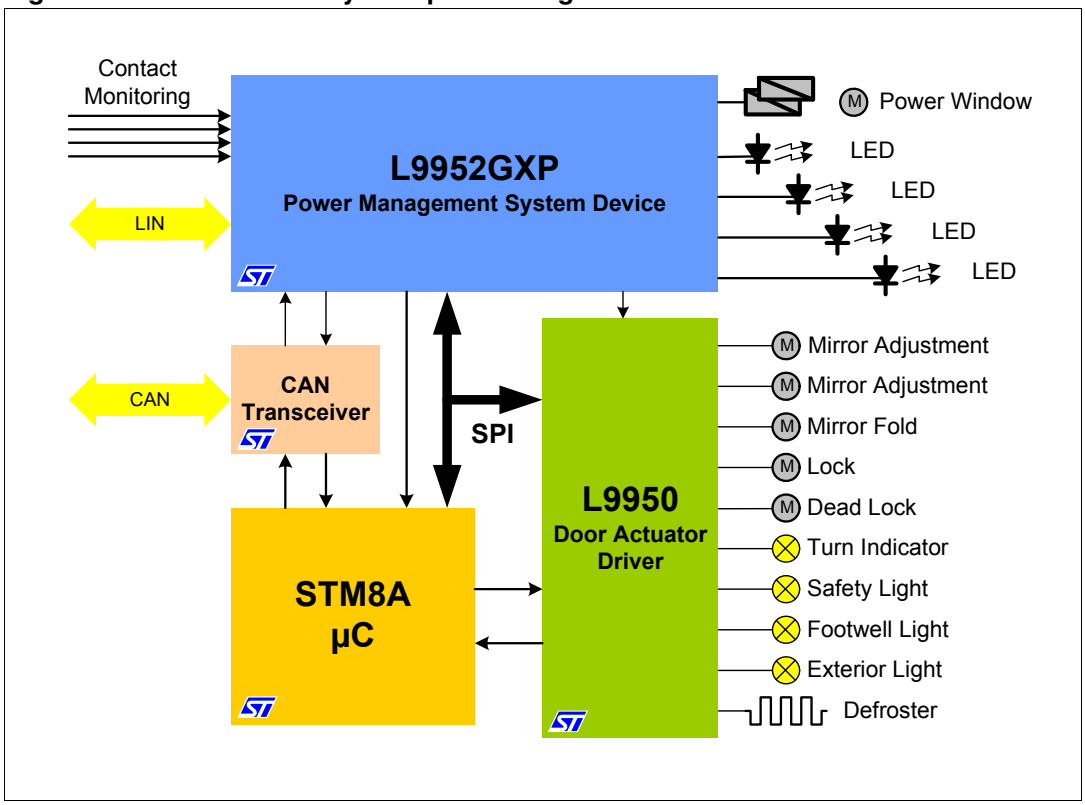
CAN	Controller Area Network
CR	Control Register
CSN	Chip Select inverted signal of SPI
DI	SPI Data-In
Dig_Out3	Digital output 3 of the L9952GXP
Dig_Out4	Digital output 4 of the L9952GXP
DO	SPI Data-Out
ECU	Electronic Control Unit
FSO	Fail Safe Output
HS	High-Side driver output
I_{CMP}	Current supervision of V1 regulator in V1_standby mode
INH	Inhibit input of L9952GXP designed for connection with CAN controller
LIN 2.1	Local Interconnect Network version 2.1 (SAEJ2602 compatible)
LINPU	Local Interconnect Network Pull-Up
LOWi	Long Open Window
LS	Low-Side Driver Output
MISO	SPI-Master In Slave Out
MOSI	SPI-Master Out Slave In
NReset	Active low Reset output signal - connected to microcontroller.
OC	Over-Current detection
OL	Open-load detection
OP	Operational sense amplifier
OV	Over-voltage failure of V_S
POR	Power-On Reset
PWM	Pulse Width Modulation signal
REL	Relay Output-e.g. low side driver
SPI	Serial Peripheral Interface
SR	Status Register
TRIG	Trigger bit to be inverted within a Window Watchdog
TSD	Thermal Shutdown
TW	Temperature Warning
UV	Under-Voltage failure of V_S

Vbat_standby	Vbat_standby mode
V1_standby	V1_standby mode
WDC	Watchdog Counter
WD	Watchdog
WU	Wakeup input of the L9952GXP
WU1..4	All 4 wakeup inputs of the L9952GXP

1 System description

The L9952GXP is specified for targeting microcontroller based automotive applications such as door modules, body control units and mechatronic subsystems. Thanks to its advanced functionality and wide ranging configuration possibilities, this power management system IC could either address automotive embedded applications than industrial ones.

Figure 1. Door module system partitioning

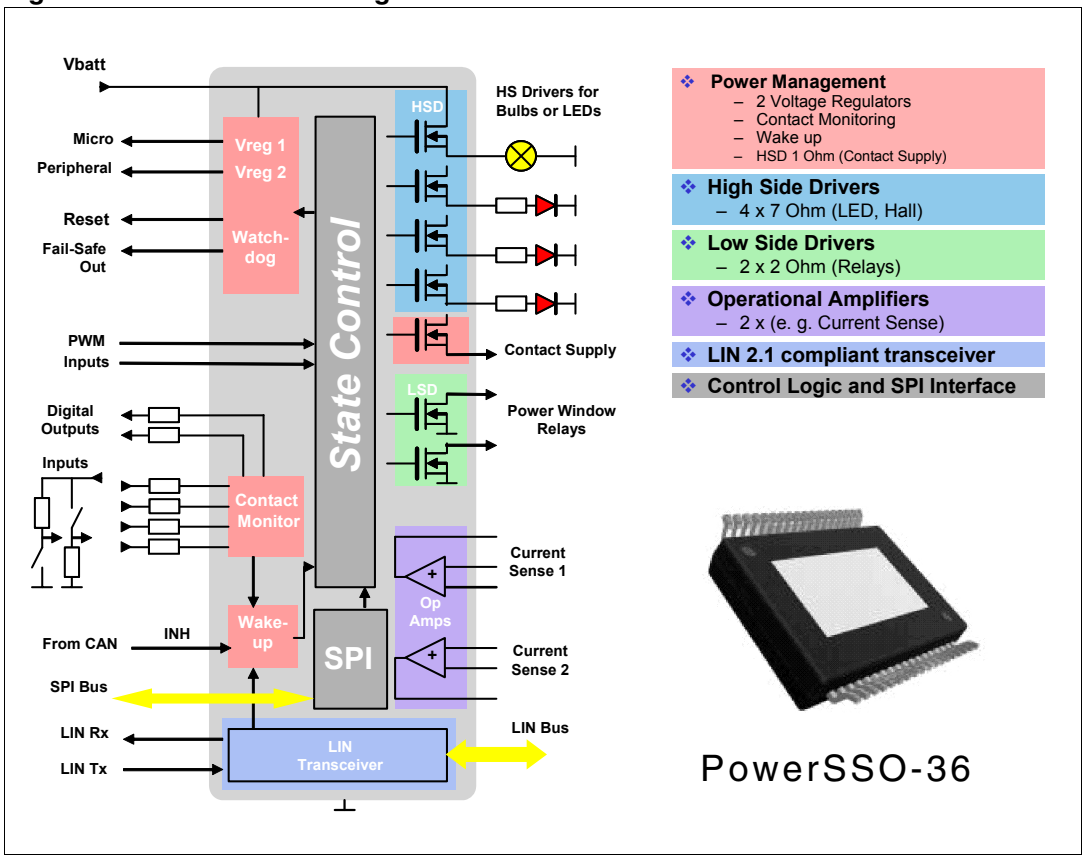


Due to the tight interdependence between the L9952GXP and its supplied microcontroller, the L9952GXP will also be called “**Companion Chip**” in this document.

1.1 Internal block diagram

Figure 2. highlights the L9952GXP main internal functional blocks.

Figure 2. Internal block diagram



The L9952GXP is a power management system IC containing two low drop regulators with advanced contact sense and additional peripheral functions. The integrated standard serial peripheral interface ***SPI*** controls all internal operations and provides driver diagnostic functions.

For a complete and detailed description of all internal features please refer to the L9952GXP product specification.

1.2 Key features

The **L9952GXP** integrates the following key features:

- **Two very fast transient response voltage regulators** - without electrolytic capacitance
- **Ultra low quiescent current** in standby mode (7 µA)
- **LIN 2.1** compliant transceiver
- Configurable **contact monitoring** - Static, Cyclic, Filtering
- Configurable **wakeup procedures** through wakeup Contacts, LIN, CAN, SPI
- **Window watchdog** and **fail safe functionality**
- Exhaustive **system diagnosis** through SPI Interface
- Advanced **configurable peripherals**
  - Five High side drivers (1 x 1 Ohms R_{DSON} and 4 x 7 Ohms R_{DSON})
  - Two low side drivers
  - Two operational amplifiers with high output voltage
  - Two configurable timers with on-chip oscillator
  - Two PWM inputs

The key benefits that can be obtained by integrating a L9952GXP in your subsystem are numerous: From the very low system quiescent current, through the cost efficient integration of peripheral functions and the diagnostic features, most of your concerns can be easily and efficiently covered. The following chapters will show you how.

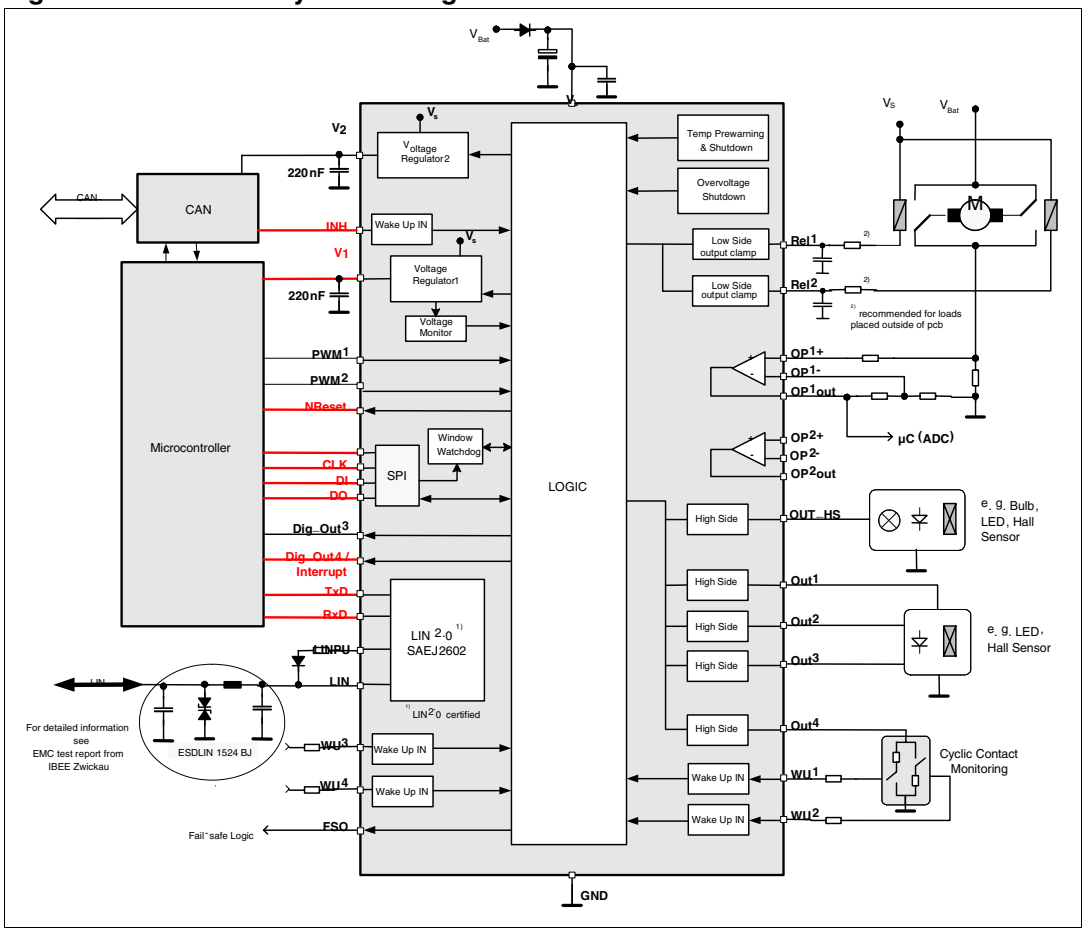
1.3 Standard system configuration

This application guide helps to operate the L9952GXP device. Prerequisite for this guide is to use the L9952GXP in the standard configuration of the system hardware. For this standard configuration the detailed behaviour is described under various conditions. If the device is used in other conditions, the behaviour may differ from this description.

Figure 3. gives an example of a system configuration for designing a power window application. This picture is intended to present most of the interconnection possibilities between L9952GXP, microcontroller, external CAN transceiver, LIN Bus, loads, actuators and sensors.

We will first focus on the interconnections between the L9952GXP and the microcontroller. These connections are the most important ones in order to start to operate the device and get used with its functionalities.

Figure 3. Standard system configuration



The required signals (red coloured) for the standard interconnection between the L9952GXP and microcontroller are:

- **V1** (power supply to microcontroller)
- **NReset** (reset signal to microcontroller)
- **SPI** (DI, DO, CLK, CSN)
- **Dig_Out4/INT** (if interrupt mode is required)
- **LIN_RxD** and **LIN_TxD**
- **INH** (from CAN transceiver INH output)

The following signals can also be connected but are not required for the basics operations of the L9952GXP:

- PWM1 and PWM2 (to enter FLASH mode)
- Dig_Out3

2 Operating modes

The L9952GXP power management system IC can be operated in three different major modes:

- **Active** mode (including Start-up and Flash modes)
- **V1_standby** mode ***V1_standby*** (with or without contact sense)
- **Vbat_standby** mode ***Vbat_standby*** (with or without contact sense)

Depending on the targeted application, a combination of these modes has to be implemented.

The following examples highlight some very different requirements:

- The application needs up to two independent low-drop voltage regulators, High-Side and Low-Side drivers with advanced diagnostic functions and current-sense operational amplifiers.
- The application must continuously supply the microcontroller in order to preserve its memory content.
- The application targets a minimum current consumption and all current sources have to be switched-off when the functional tasks have been completed.
- The application must periodically monitor external sensors and has to perform specific tasks in case of status change or bus activity.

For all these different scenarios, the L9952GXP can provide a suitable and cost-effective solution.

The following figures highlights the different operating modes and the main transitions possibilities between these modes. Please refer to the L9952GXP datasheet document – Figure 3 – operating modes – for further details.

- ***Active mode*** covers all the configurations where V1 voltage regulator (microcontroller supply) and L9952GXP outputs (HS and LS drivers) need to be continuously supplied. In active mode, all outputs can be enabled or disabled via SPI control registers access. The V1 regulator can deliver up to 250 mA and V2 regulator up to 100 mA. During Active mode the microcontroller has to trigger periodically a window watchdog.
  - ***Start-up mode*** is a temporary state of the L9952GXP after power-on. During Start-up all internal registers are initialized to their default values and the Cold Start flag (SR0 bit 19) is set for monitoring the power-on event. This mode is immediately followed by the Active mode.
  - ***Flash mode*** operates identically to the active mode except the watchdog feature. This mode is needed for microcontroller re-reprogramming purpose: while flashing the microcontroller cannot manage its software routines anymore - This is why the watchdog has to be disabled. For safety reason this mode can only be entered by applying a high voltage signal on PWM2 pin (V_{PWM2} > 9 V).
- ***V1_standby mode*** is a low current mode intended to preserve the RAM content of the microcontroller during low activity phases. Apart from V1 regulator all other outputs and internal loads are switched off. Typically the current consumption without cyclic sensing falls-down to **45 µA**. During V1_standby mode, it is also possible to activate the **cyclic sensing** of external contacts. A standard operating procedure has to be followed

before entering V1_standby mode. All details on this procedure are explained in the “Preparation for Standby” paragraph.

- ***Vbat_standby mode*** is intended to minimize the current consumption. All the L9952GXP internal functions are switched-off except the ones for waking-up the device. In Vbat_standby mode the current consumption is reduced to **7 µA** typical. During Vbat_standby mode, it is also possible to activate the **cyclic sensing** of external contacts. Depending on applied settings for external contact supply and contact sense, the current consumption will be in a range of **75 µA** typical. A standard operating procedure has to be followed before entering Vbat_standby mode. All details about this procedure are explained in the “Preparation for Standby” paragraph.

3 Initialization

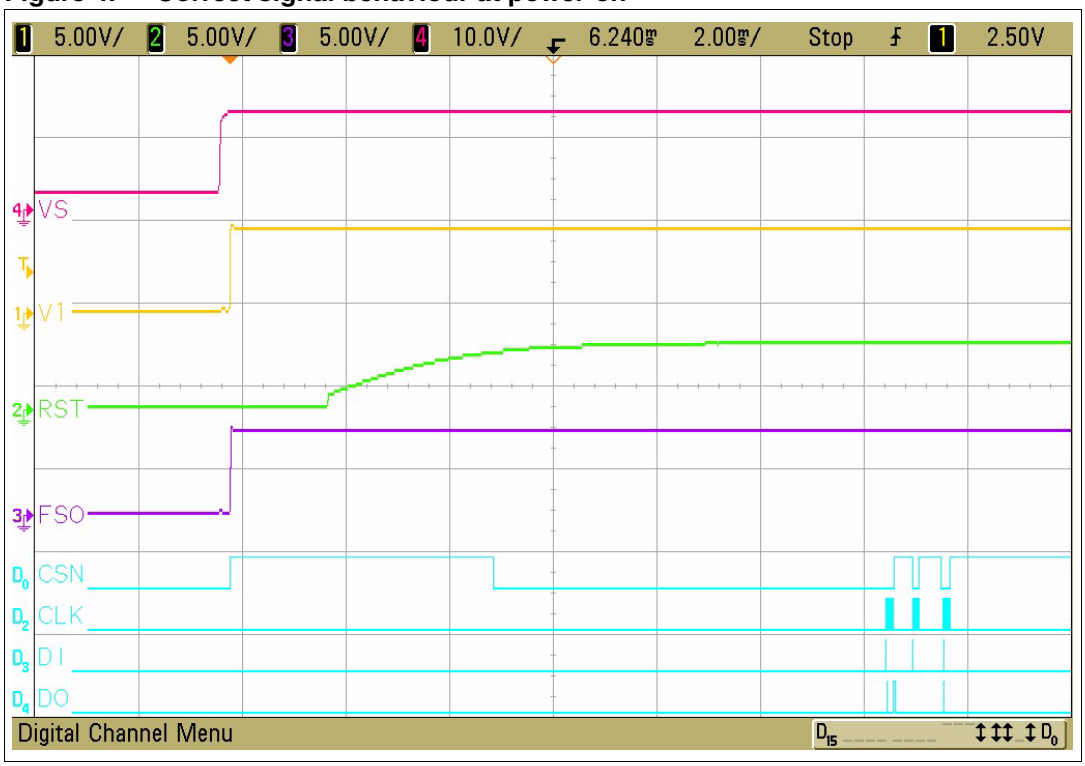
3.1 Power-on

Figure 4. shows the main signal behaviour after power-on. When Vs voltage is applied, the V1 voltage supplying the microcontroller is immediately turned On thanks to its very fast transient response. Note that no external electrolytic capacitance is needed.

The *Fail Safe Output (FSO)* is switched to its inactive state - high. However the microcontroller does not know at that time whether a power-on or a wakeup event from any standby mode occurred. Finding the origin of the microcontroller restart is the topic of the initialization diagnosis. Typically the microcontroller power supply - connected to the V1 voltage regulator - is switched off in power off state, Vbat_standby mode and in the case of a hard restart after several successive fails (e.g. 7 successive watchdogs fails).

The microcontroller is restarted by NReset after a wakeup from V1 or after a watchdog fail. During the power-on diagnosis, the root cause of the microcontroller restart should be identified and action taken regarding the previous state. Since after NReset or V1 turn-on the watchdog starts with Long Open Window, all this power on diagnosis has to be done before the Long Open Window expiration (65 ms typical), otherwise the power-on diagnosis will have to be re-started from scratch without any diagnosis on the restart reason or Cold Start event.

Figure 4. Correct signal behaviour at power-on

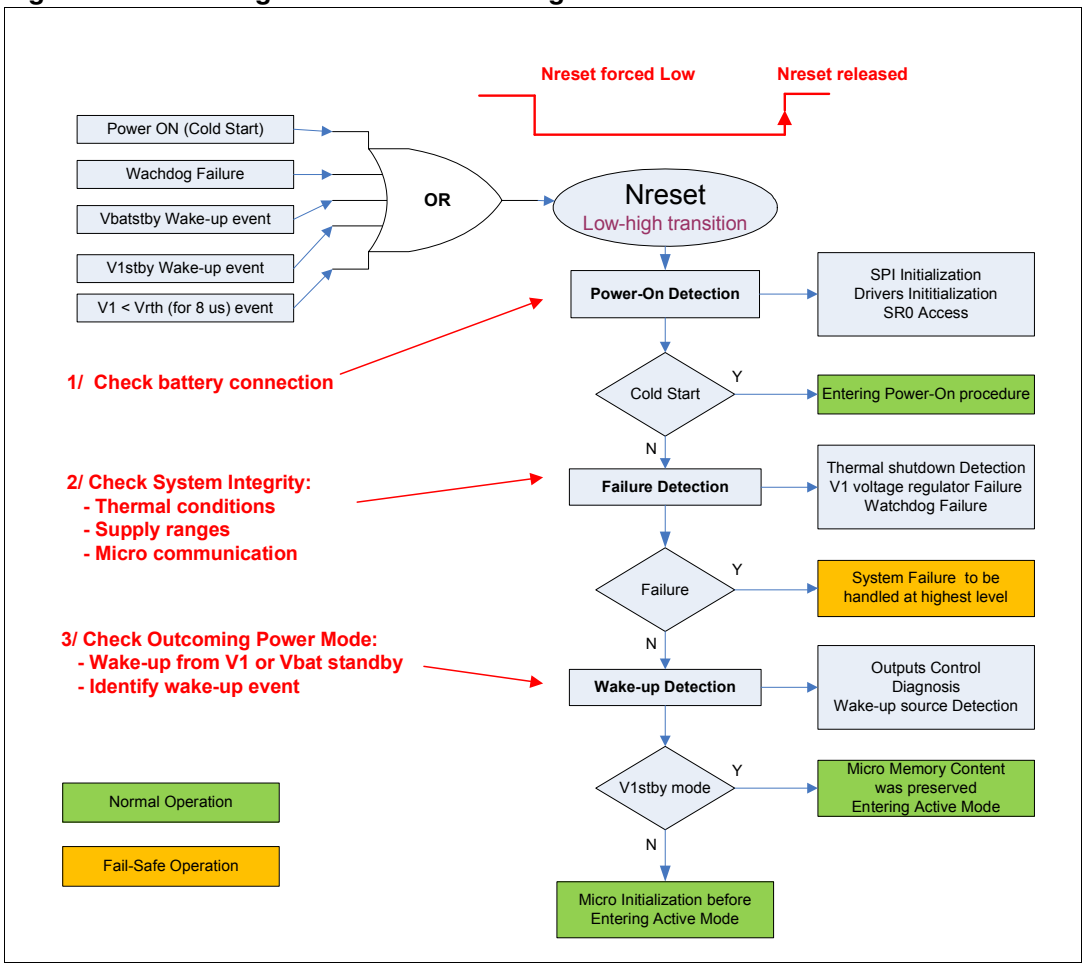


3.2 NReset generation

On an automotive system application, many external events - predictable as well as unpredictable ones - may be at the origin of a L9952GXP NReset generation. Depending on supply conditions, thermal conditions, voltage range stability or wakeup events, different diagnosis and actions have to be handled by the application with the highest level of confidence and security.

The following flowchart (*Figure 5.)* is a reduced overview of the NReset handling in order to treat the possible events in the right priority order. The complete and exhaustive diagnosis procedure is detailed in the Diagnosis chapter. In addition, the dedicated software routine has been inserted in the appendix.

Figure 5. NReset generation and handling overview



After L9952GXP power-on - when Vs voltage is turned On - the first action to be performed by the application is the Initialization Procedure.

First the status register ***SR0*** has to be accessed in order to evaluate the cold start bit (SR0 bit 19). The SR0 should be obtained by a CR2 write. After cold start bit evaluation, the SR1 should be read for evaluation of a possible restart after any error. If thermal shutdown neither V1 fail nor WDC Fail Counter is set, there is only wakeup from Vbat_standby mode

or wakeup from V1_standby with NReset generation as possible reasons for microcontroller restart.

At this point it is not possible to determine whether the microcontroller was restarted because of power-on or wakeup event from any standby mode. Details regarding wakeup from standby modes as well as explanations on the corresponding parts of flow chart will be deeply described in the Diagnosis chapter. This chapter is aimed to give an initialization overview only.

At the end of power-on diagnosis the watchdog has to be triggered by writing TRIG = 1. As soon as the watchdog is triggered the Long Open Windows expires and the Window Watchdog (WD) is started. It has then to be triggered periodically – typically every 10 ms from the last trigger operation.

3.2.1 Power-on: cold start detection

This first step is used for checking system supply status. After power-on, when the supply voltage Vs passes the Power-on-Reset (*POR)* threshold (3,8 V typical), the ***"cold start"*** *bit (SR0 bit 19)* is latched. Consequently all SPI registers are initialized to their default value. Only a power-on event latches the cold start bit - It is NOT set after waking-up from any standby mode or after any failure occurrence (Thermal Shutdown, V1 Fail, WD Fail…).

Only the first SR0 read access immediately following a power-on returns the cold start flag. This bit is cleared after the first complete SPI frame completion, precisely when the CSN signal is relaxed (rising edge). A complete SPI frame means that 24 SPI_CLK pulses were transmitted while the SPI_CSN signal was low. In the case of an SPI communication Fail, for example, a short on the SPI_CLK signal – the cold start bit is held at 1 until the next SPI frame completion.

3.2.2 Failure detection

Vs power supply: under/over-voltage detection

The Vs under/over voltage flags are used to point-out static problems on Vs supply – for example, on the battery (Vbat). By default the sporadic under/over voltage events are not saved, the L9952GXP turns the outputs in high impedance state for load protection and automatically recovers its functionality when the under/over voltage condition has disappeared. For safety reason, two control bits have been implemented to precisely control the outputs behaviour in case of over/under-voltage event.

Please refer to the Diagnosis Chapter for an exhaustive description of this Diagnosis.

$V_{1,2}$ voltage regulators: failing supply detection

It may be mandatory in safety related applications, to monitor the subsystem microcontroller RAM consistency and if needed to take corrective actions from the upper layer of the application. The $V_{1,2}$ voltage regulators flags V_{1fail} and V_{2fail} will point-out disturbances even those coming from short to ground at start-up but also from very short under-voltage conditions due to electromagnetic noise.

Please refer to the diagnosis chapter for an exhaustive description of this diagnosis.

V1 fail / V2 fail are flags indicating a drop of the voltage regulator output voltage below 2V for at least 2 µs. The flags are also set after power on, if the voltage regulator output doesn't exceed the 2 V level within 4 ms after turn-on.

SHT5V2 is an additional flag for V2 shortcut diagnosis. This flag is set when the output of voltage regulator 2 doesn't exceed the 2 V level within 4 ms after turn-on.

Watchdog failure

The watchdog has to be served during the open window, typically every 10ms after previous refresh. As soon as the open window expires without a valid trigger, the WD fails. The WD also fails when it is triggered too early means during the closed window. As soon as the WD fails, the NReset signal is pulled down for 2 ms.

3.2.3 Wakeup source identification

After waking-up from V1_standby or Vbat_standby mode, an identification procedure has to be performed to find out the wakeup source or event.

The detailed flowchart of a standard procedure can be found at *Figure 28.* within Standby modes chapter. The generic microcontroller code has been included in the appendix .Those frame has to be considered as example guidelines for a safe approach. The priority goes to safety or error related information before considering potential wakeup sources. Depending on your application needs and priorities this standard frame will have to be adapted.

After a transition from one operating mode to another, the current state of L9952GXP cannot be evaluated. For this reason it is highly recommended after any wakeup event to proceed with a full initialization of L9952GXP as shown in *Figure 18.: Power-on diagnosis: detailed flowchart*.

The wakeup root cause can be identified by reading SR0 bits 13 to 18 The corresponding bits have been set in case of a wakeup by LIN, INH or WU inputs 1-4 status change. For WU inputs, the initial status was automatically stored before going to standby. A continuous comparison between the initial and actual value is operated during contact sensing and the corresponding WU input bit is set in case of a status change.

Note: The previous standby mode from which the L9952GXP was woken-up cannot be identified after any wakeup event. In case this information is needed by your application, it has to be saved into the microcontroller before going into the specified standby mode.

3.2.4 Microcontroller RAM integrity

This topic can be a very important issue depending on the application. In Normal conditions the RAM content should still be valid, if the power supply voltage didn't drop under threshold level. Regardless the microcontroller was in halt mode and NReset was processed after wakeup. Typical situations in which the RAM content should have been corrupted are power-on, hard restart after several successive fails and wakeup from Vbat_standby mode.

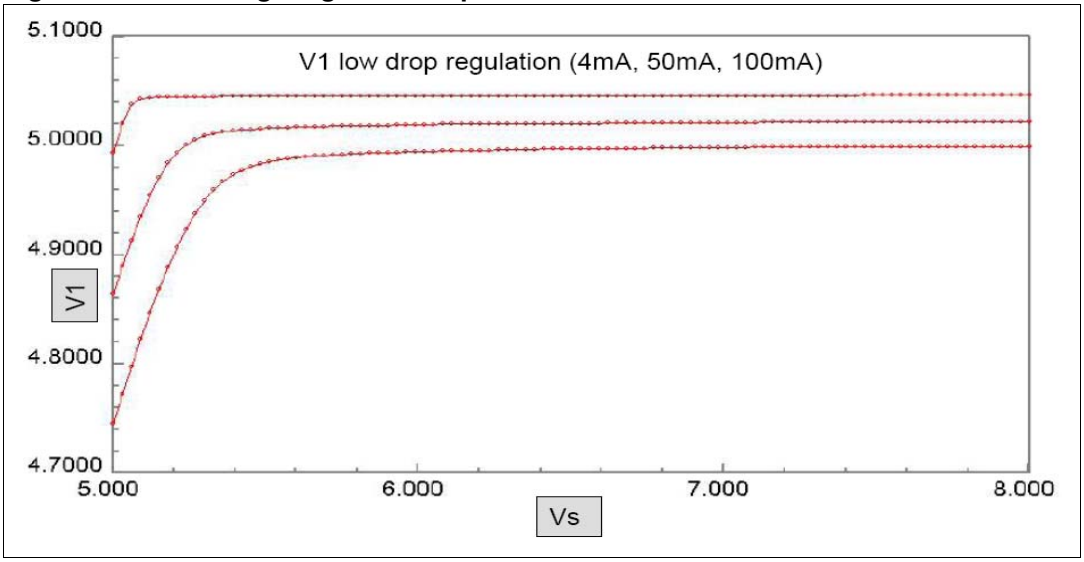
After wakeup from V1_standby mode, the RAM content should be valid. Due to the fact that the previous standby mode cannot be detected by L9952GXP itself, it will have to be decided – at the application level – whether the RAM content is valid or not. Some microcontrollers integrate power on detection feature that facilitates such arbitration.

3.3 User defined initialization

Such initializations can be done anytime during run time, but in most applications it is enough do it after start up only.

NReset level is the threshold level of V1 voltage when the NReset pin is pulled-down. This situation can occur only during V_S voltage around the under-voltage level and the current of V1 near the limit of over current protection. The V1 regulator has low drop and the output voltage shouldn't fall under the NReset threshold in standard current range for Vs in operational level. Drop of V1 voltage regulator and voltage level at output in dependence on Vs value and V1 current is shown in *Figure 6.*.

Figure 6. V1 voltage regulator drop



Vs lockout is a control bit which controls the behaviour of the high side output Out 1..4, Out_HS of the low side relay outputs Rel1 and Rel2 and of the LIN Bus in case of Vs over-/under Voltage conditions. When V_S lockout bit is set the outputs are automatically disabled-means turned-off to their default value when an over/under voltage condition is detected. The outputs remain off also when the over/under voltage condition disappears. The over-/under-voltage Status Bits (SR1, D0/D1) have to be cleared in order to turn-on the outputs.

If the Vs lockout bit is not set (default configuration), the outputs are automatically turned On when the over-/under-voltage condition disappears.

4 Watchdog operation

4.1 Initialization - Long Open Window (*LOWi)*

After some specific events, the L9952GXP's window watchdog counter will start to operate with a Long Open Window (*LOWi)* - typically 65 ms.

The events at the origin of a LOWi are the following:

- " Cold " NReset after power-on.
- " Warm " NReset under Vs supply.
- " Wakeup " from Vbat_standby or from V1_standby modes.
- " Watchdog Failure ".
- " V1 Voltage regulator current increased above the threshold current in V1_standby mode-e.g. Iv1 > Icmp_rise.

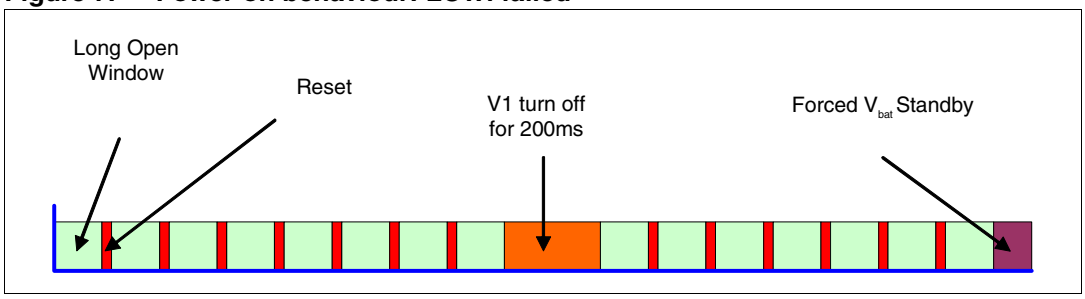
The Long Open Window *(LOWi*) allows the microcontroller to run its own setup through its boot sequence or to recover its normal activity after a "low-power" or "Halt" period before triggering the watchdog via the SPI interface.

During this time slot the watchdog has to be triggered indifferently between the beginning and the end of the Long Open Window.

Figure 7. describes the WD behaviour in case the LOWi expires without a valid trigger. In this case, an active low reset pulse is generated on the NReset output and another LOWi is started. After eight consecutive watchdog failures the V1 is turn-off for 200 ms. After this delay another LOWi is started. If watchdog is still not triggered after seven further consecutive reset procedures, the V1 regulator is completely turned-off and the L9952GXP device goes into Vbat_standby mode until next the wakeup event occurrence (e.g. via LIN, CAN/INH).

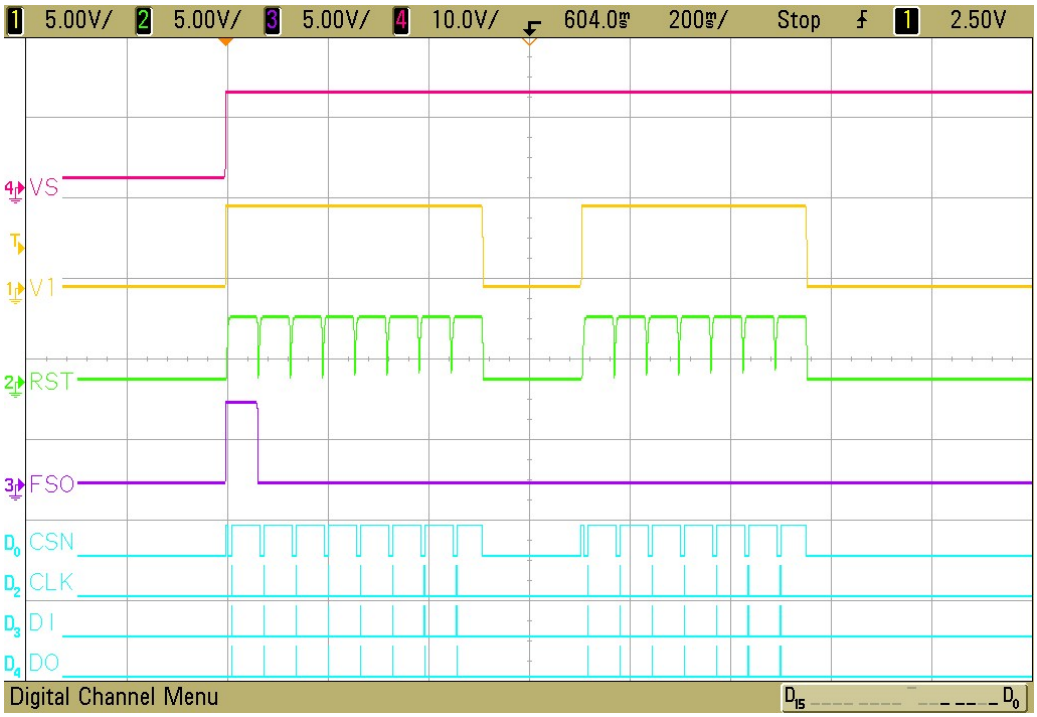
When the watchdog is triggered before the LOWi expiration the initialization procedure is over. The microcontroller will then have to trigger the watchdog within the standard periodic open windows (typically every 10 ms).

Figure 7. Power-on behaviour: LOWi failed



Screenshots of the signals behaviour after a power-on with continuous watchdog failures are shown in *Figure 8.*. As the watchdog was not triggered 15 consecutives times, V1 was switched-off and the device forced to Vbat_standby mode. After the first Long Open Window failure, the Fail Safe Output *(FSO)* is turned to active (low) state. This output remains active till the next successful watchdog trigger. If the device is switched to force Vbat_standby mode, after wakeup the FSO output is for the first Long Open Window in not active state again until the new watchdog failure occurs (see *Figure 8.*).

Figure 8. Power-on procedure without watchdog trigger

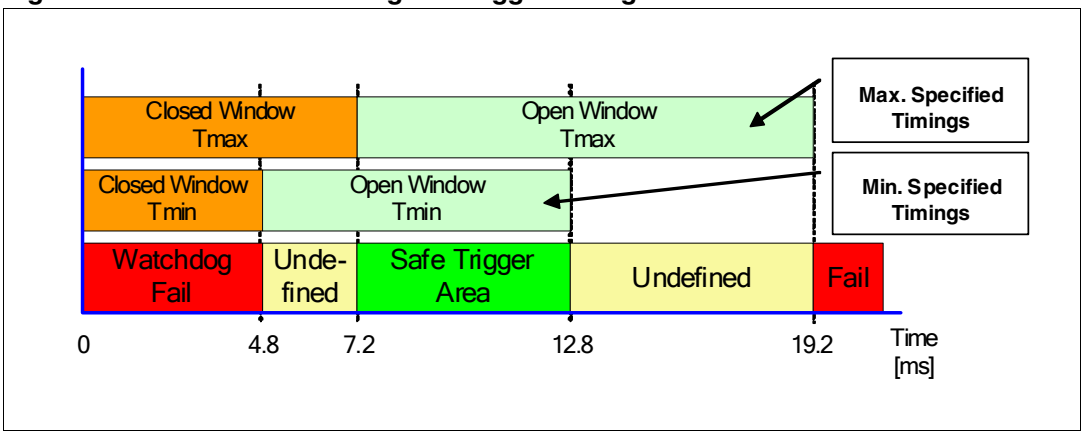


4.2 Normal operation - window watchdog

The window watchdog procedure enables periodic control of the microcontroller during normal Operation (Active mode). Any unexpected deviation of the quartz period (even too slow or too fast) may lead to dysfunctions and have dramatic consequences in some security related applications. Thanks to the Watchdog Trigger procedure, both sustainability and correctness of the microcontroller's frequency are permanently checked.

Figure 9. shows the different watchdog trigger behaviours we can obtain depending on the different corner conditions. A correct watchdog trigger starts the window watchdog with a closed window (from 4.8 ms min. to 7.2 ms max.) followed by an open window (from 8 ms min. to 12 ms max.). The micro has to serve periodically the watchdog by alternating the trigger bit ***TRIG*** (CR0-D19) during the open window. A correct watchdog trigger signal will immediately starts the next closed window.

Figure 9. Windows watchdog and trigger timing areas



Note: The silicon parameters and the corner conditions have a strong impact on the Windows Timings. To avoid any potential Watchdog Failures at extreme conditions, ***it is highly recommended to trigger the Watchdog in the middle of the Safe Trigger Area - means at 10ms****. A WD trigger during the undefined area could either be detected as correct or a failing Trigger. WD triggering during a closed windows will causes an "Early write" trigger failure. In this case the L9952GXP resets the microcontroller - means NReset Pin is pulled low for 2 ms.*

Naturally, it is possible to perform at any time a CR0 write access, but the microcontroller has to make sure that the ***TRIG*** bit Polarity (CR0-D19) remains unchanged outside the safe trigger area otherwise an "Early write" trigger failure may occur.

4.3 Watchdog fail

The watchdog ***(WD)*** has to be served during the open window, typically every 10 ms after previous refresh. As soon as the open window expires without a valid trigger, the WD fails. The WD also fails when it is triggered too early means during the closed window. As soon as the WD fails, the NReset signal is pulled down for 2 ms. All outputs are switched off, the FSO output is forced active (low) and the watchdog counter ***(WDC)*** (SR1 bits 12 to 15) is incremented e.g. set to 1. After 2 ms, NReset is released to inactive (high) state and the Long Open Window (*LOWi)* starts.

Note that after waking-up from any standby modes, and during the complete LOWi, the outputs recover the same value as before entering the standby mode. **Important is that all outputs are switched off in case of WD failure.**

Before the first LOWi expiration, the WD has to be triggered. If the WD is triggered successfully, FSO is switched to inactive (high) and all outputs are configured to their defined values (written in CR0 together with the WD trigger command).

If the WD trigger fails again during LOWi, e.g. LOWi expires without triggering, the NReset is processed again and the WDC is incremented. After 8 successive LOWi without watchdog triggering, the V1 is switched off. After 200 ms V1 is switched on again and 7 additional LOWi are issued. If the WDC reaches 15, L9952GXP is forced to Vbat_standby mode and the WDC is cleared. WDC is also cleared after any valid watchdog trigger. Therefore, if your application wants to monitor the number of successive watchdog failures, the WDC status (SR1 bits 12 to 15) has to be read after any reset event and before watchdog triggering

5 Outputs control

5.1 Outputs descriptions

The L9952GXP provides a complete set of outputs for driving different kinds of loads:

- **Two 5V low-drop voltage regulators** (250 mA and 100 mA continuous mode)
- **Five high-side driver outputs** for driving LEDs, Bulbs or Hall Sensors
- **Two low-side driver outputs** for driving relays
- **Two digital outputs** for driving microcontroller digital inputs

After Vs power-on, CR0, CR1 and CR2 registers are at default value **0x000000**. This means that all outputs are switched Off.

Note: ***Important : Outputs behaviour after a failing watchdog***

After a first WD failure, all L9952GXP outputs are turned Off. They cannot be turned on (even during LOWi) until the watchdog is served correctly. As the HS output control bits remain unchanged, the HS outputs will enter the configured state automatically if the watchdog is triggered correctly or after waking-up from forced Vbat_standby mode.

5.1.1 Voltage regulator V1

The V1 voltage regulator is the core functionality of the L9952GXP and particular efforts have been spent both for improving the performance and for optimizing the complete system area.

As a result the L9952GXP offers strong differentiating features for serving your application needs:

- Very low quiescent current
- Optimized transient response
- No electrolytic output capacitor need
- Continuous I_{CMP} current monitoring functionality
- Advanced protections against overload, over-temperature, short circuit, reverse biasing

Exhaustive information on V1 voltage regulator is available in Diagnosis and Standby modes chapters. Additionally an information summary in Appendix B covers some specific scenarios regarding V1fail and I_{CMP} monitoring topics.

Note: *The V1 voltage regulator is also used for supplying internal logic circuitry and digital outputs of the L9952GXP (Dig_out3, Dig_out4 and FSO). As a consequence I_{CMP} is the sum of the V1 external current plus the internal logic circuitry and Digital outputs currents.*

5.1.2 Voltage regulator V2

Voltage regulator 2 has 4 different operating modes:

- Always Off in all power modes
- Always On in all power modes
- On in run mode only and Off in standby modes
- On in active mode and V1_standby mode; Off in Vbat_standby mode

After voltage regulator V2 has been turned On, the SHT5V2 flag (SR0 bit 12) should be checked to get a status of the regulator output and connected load condition. Details about this flag can be found in diagnosis chapter.

5.1.3 High-side drivers

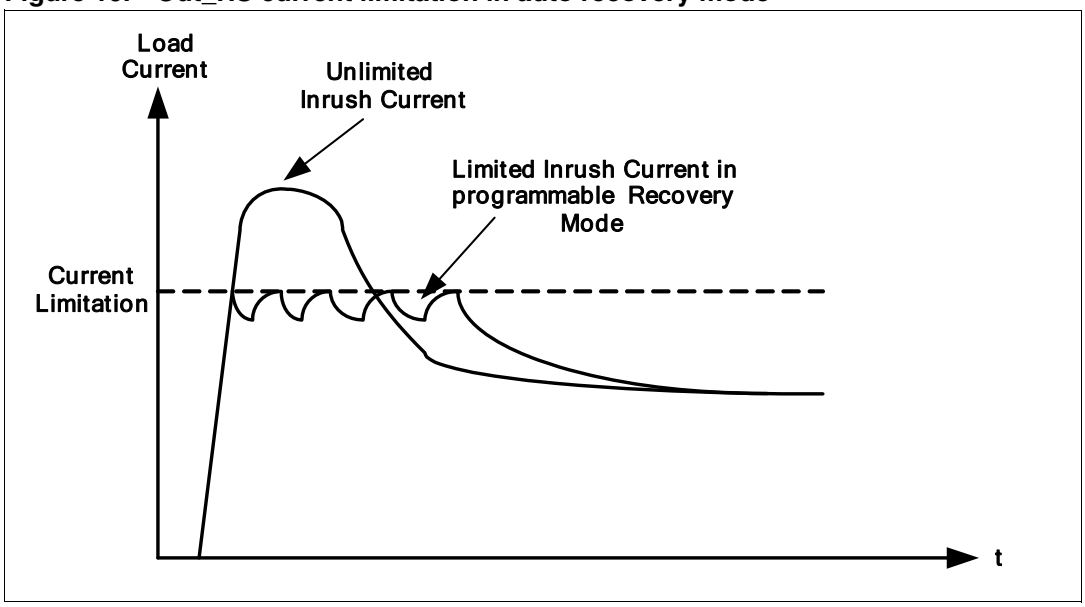
Any of the five High-side outputs can be configured to one of the following modes by setting the corresponding combination of bits in the CR0:

- **Off** – in this mode the output is switched Off in all operating modes.
- **On** – in this mode the output is switched On in Active mode and it is switched Off in V1_standby and Vbat_standby modes.
- **PWM 1 or PWM 2** – in these modes the output signal is controlled by the signal on the PWM1 or PWM2 input in Active mode. In V1_standby or Vbat_standby mode the output is switched off.
- **Timer 1 or Timer 2** – in these modes the output is periodically switched on and off according to the setting of the selected timer. Typically this mode is used to periodically supply the external contacts, synchronized with the cyclic monitoring of the wakeup inputs. This configuration is possible in all operating modes.

Additionally, on HS Out1 to HS Out4 the open load threshold levels can be configured to 2 mA or 8 mA (CR0-D0…D4).

For Out_HS an auto recovery feature is available in active mode (see *Figure 10.*). This enables driving loads with an initial current higher than the over current limit (e. g. inrush current of cold light bulbs). If the Auto-recovery ***O_HS_REC*** bit is set (CR2-D5), Out_HS will automatically be restarted after any over-current shutdown event.

Figure 10. Out_HS current limitation in auto recovery mode



5.1.4 Low-side drivers

Two low-side driver outputs Rel1 and Rel2 are available for driving external relays – e.g. for power window control. These outputs can be switched on and off by setting the corresponding bits in the CR0.

The Rel1 and Rel2 output control bits are cleared by default after a first watchdog failure occurrence. Refer to the chapter “Driver Control after power-on” for detailed information.

5.1.5 Digital outputs

In both Active and V1_standby modes, the Outputs Dig_out3 and Dig_out4/INT offer the possibility to transmit real time signals from the operating side to the processing side of the application without waiting for a periodical SPI access. Three different configurations are possible:

- Direct looping of WU inputs when status changes.
- Direct looping of High-side open-loads when status changes.
- Interrupt generation when waking-up from V1_standby mode.

A significant advantage of direct looping is the possibility to transmit signals coming from the WU inputs pins - at Vs voltage level to the digital output pins - at TTL voltage level e.g. 5V.

The direct looping of open-load status from High-Side outputs was specifically implemented to connect Hall sensors outputs requiring high real time processing speed. For this purpose the open-load threshold current is configurable on HS Drivers 1 to 4 between 2mA and 8mA (CR2 -bits 0 to 3).

Additionally, the Dig_out4/INT output can be configured (CR1 bit 20) to generate an interrupt signal to the microcontroller (2ms active high pulse) in case of a wakeup from V1_standby mode through WU inputs, LIN, INH, SPI, HS open-load and $I_{V1} > I_{CMP\_ris}$. When INT_enable is set to 1 (CR1 bit 20) the looping Option on Dig_out4 is disabled and the **NRESET generation is disabled**. This specifically addresses applications where the microcontroller must preserve its memory content and have a fast wakeup and fast recovery after an interrupt generation.

All factors influencing the information at the digital outputs are detailed in the digital output chapter.

5.2 Outputs control after power-on

All L9952GXP outputs can be switched-on after power-on as soon as the NReset signal has been released untill expiration of the LOWi.

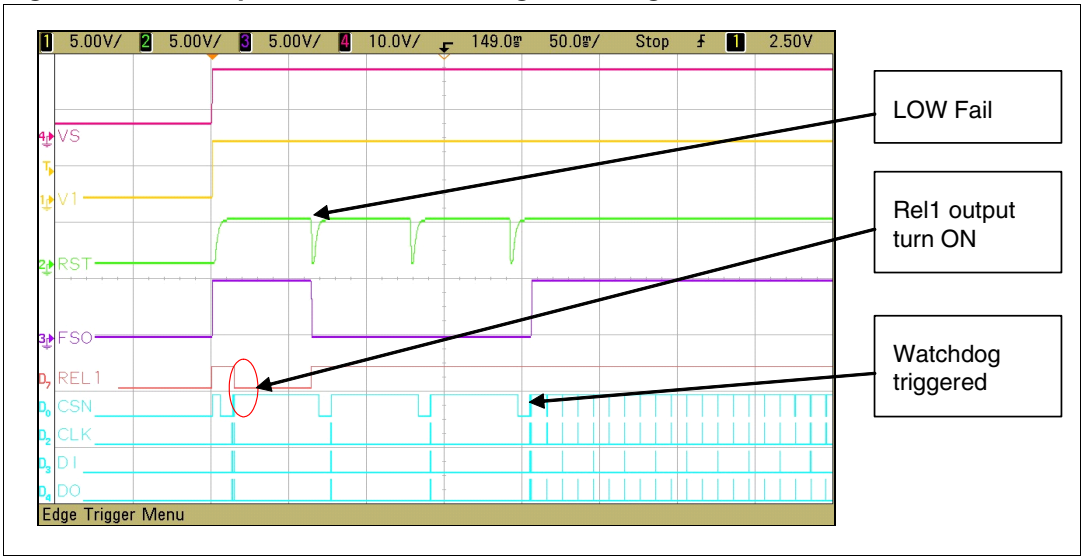
For CR0 write access, the TRIG bit has to be considered with special care. After power-on (means Cold-Start bit is set) the trigger bit polarity has to be set to “1”.

If the outputs are turned On, and watchdog is not triggered, they stay On until the long open window expires. Then the outputs are automatically disabled (turned Off and blocked until a correct watchdog trigger or a wakeup from forced Vbat_standby mode occurs); HS Control Bits in CR0 remain unchanged; LS control bits in CR0 are set to 0) and ***FSO*** is turned to active (low) state. After NReset generation, outputs stay off until first successful watchdog trigger. However, every correct watchdog trigger defines the value of all output configurations. So when the watchdog is triggered the outputs are set to configuration that was sent to the L9952GXP during this watchdog trigger procedure (Trigger bit and output

control bits are both located in CR0). On the next screenshot is caught behaviour when REL1 output was turned On after power on. But the watchdog was not triggered and long open window fails 3 times. Than the watchdog was triggered correctly by CR0 with a default value where all outputs are turned off.

Note: In case of V1_standby mode wakeup event (LIN, INH), the trigger bit was not reset to '0' by NReset event. The previous trigger bit polarity should have been stored by the microcontroller in order to correctly invert it after waking-up. otherwise the WD is triggered with a wrong Trigger bit and the LOWi is closed with a Watchdog failure.

Figure 11. LS output behaviour at failing watchdog



Refer also to *Figure 12.* and observe the REL1 behaviour in a different scenario.

5.3 Fail Safe Output (*FSO)*

The fail safe output is a standard automotive safety functionality implemented for reporting abnormal behaviour of any power management system IC.

In the case of an active FSO signal, external Safety Logic or an additional microcontroller will take-over the control of the security related Drivers so that system sustainability is assured.

The following four events force the FSO output signal to active low state:

- Entering Vbat_standby mode
- Watchdog failure
- V1 under-voltage
- Second thermal shutdown level - TSD2

The next screenshot illustrates a situation where the LOWi fails 15 times after power-on and the device is switched to force Vbat_standby mode. First after power-on, the FSO output remains in its inactive state - high until expiration of the first LOWi. As the watchdog has not been triggered during the LOWi, the device detects a watchdog failure and the FSO signal is

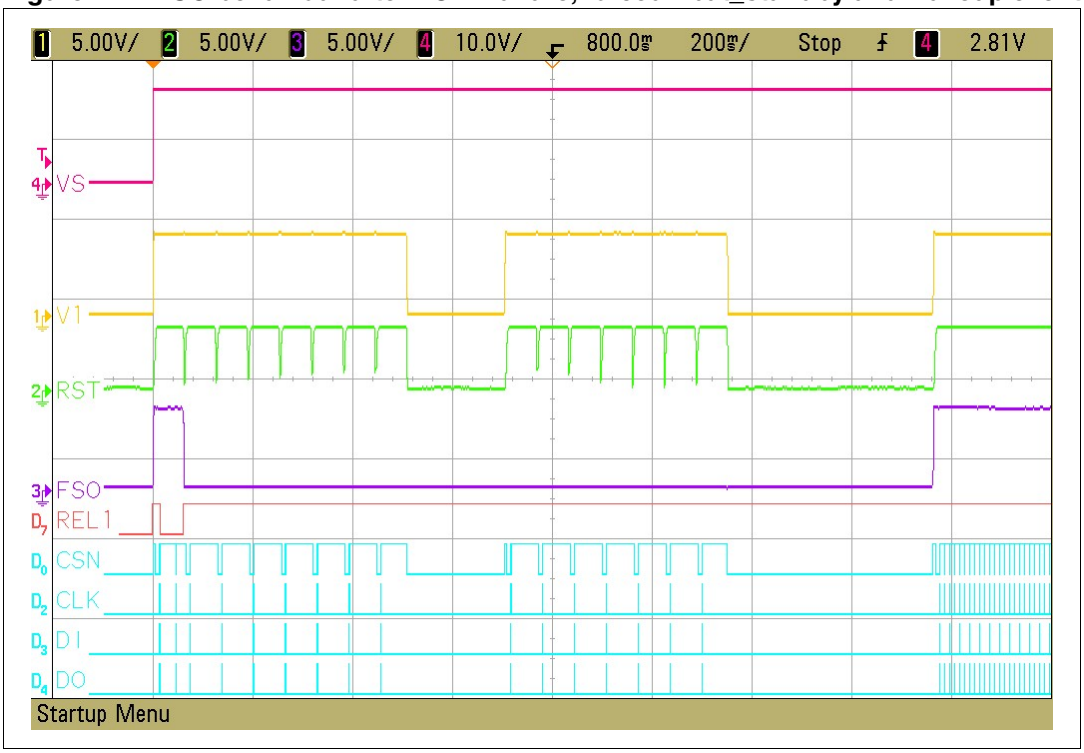
forced to its low active state. The FSO signal remains active until the Watchdog is correctly triggered.

In case the watchdog is correctly triggered before the first LOWi expiration, the FSO stay in inactive state and the L9952GXP outputs are set to the user-defined state, transmitted through the watchdog trigger SPI frame (same write access on CR0 control register).

Note that after wakeup, the LS Output remains Off due to the previous watchdog failure.

The Rel1 output is turned Off at the first watchdog failure and stays off even after a wakeup from forced Vbat_standby mode because the REL1 and REL2 control bits have been cleared after the watchdog failure.

Figure 12. FSO behaviour after LOWi failure, forced Vbat_standby and wakeup event



Refer also to *Figure 11.* and observe the FSO behaviour in a different scenario.

Note: Outputs behaviour during active FSO.

As soon as FSO enters its active low state, all L9952GXP outputs are turned Off. They cannot be turned On (even during LOWi) until the FSO is released – e.g. the watchdog is served correctly. As the HS output control bits remain unchanged, the HS outputs will enter the configured state automatically if the watchdog is triggered correctly or after waking-up from forced Vbat_standby mode. Due to the fact that the trigger bit is within the same register than the Outputs configurations bits, you should take care to overwrite the output configuration with the correct values each time you will invert the trigger bit (for example by applying a software mask).

6 Wakeup inputs

Several settings can be applied on the WU input Pins in order to configure the contact sense to perfectly match with your application requirements. The following two major settings have to be considered:

- The cyclic contact sense supported by both stand-by modes.
- The static contact sense mostly adapted for waking-up from Vbat_standby mode – e.g. for applications where the microcontroller can be completely stopped and where the current consumption has to be drastically minimized.

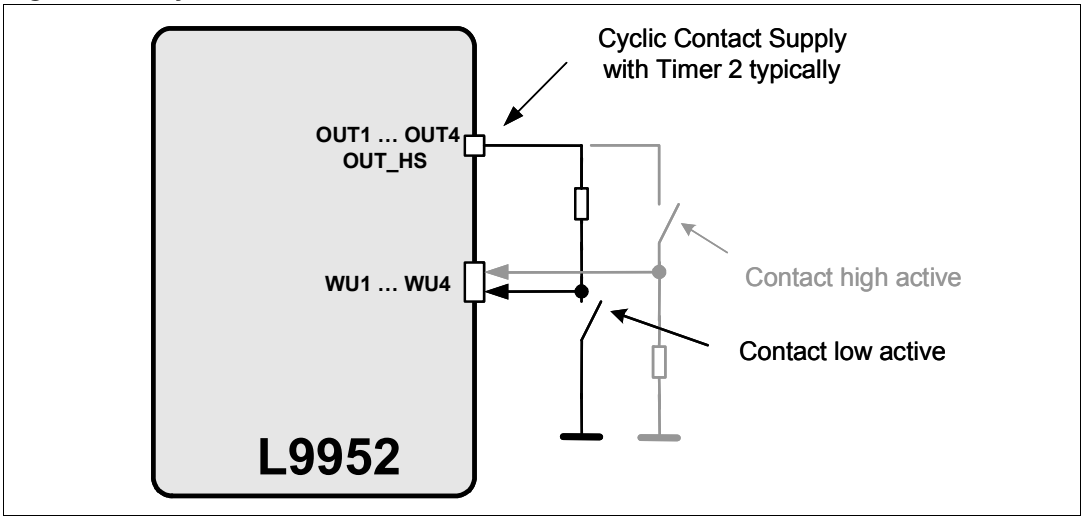
6.1 Cyclic contact sense

Both standby modes support the cyclic sense of the contacts. The main advantage of the cyclic contact supply and sense is a significant reduction in power consumption. For the open active contact (closed in not active state) the power consumption in static mode is approx 10mA for one contact. With the cyclic contact sense, this contact supply current is reduced only to a short time when the contact is checked while the current consumption of the L9952GXP increases by approximately 65uA. Contact sense is done during “On Time” of the timer selected for cyclic sense functionality. During the remaining timer period the contact is not powered and not consuming any power. Of course this feature has an effect for some contact configurations like opening contact, contact which have two stable positions (On/Off) and contacts with a parallel or a parasitic resistive load (e.g. humidity). However, regardless of the configuration, the cyclic monitoring limits the current consumption in case of a stuck contact switch.

To reduce power consumption in the timer Off-time, the proper configuration of each input for current sink or current source has to be done (CR1). The current sink or current source configuration is active only in timer Off Time for cyclic sense to reduce WU input leakage current when the contact is not powered and floating. In time when the contact is checked (timer On Time), the WU input is automatically reconfigured to the setup used in Active mode where an internal pull down of 200 KΩ is activated.

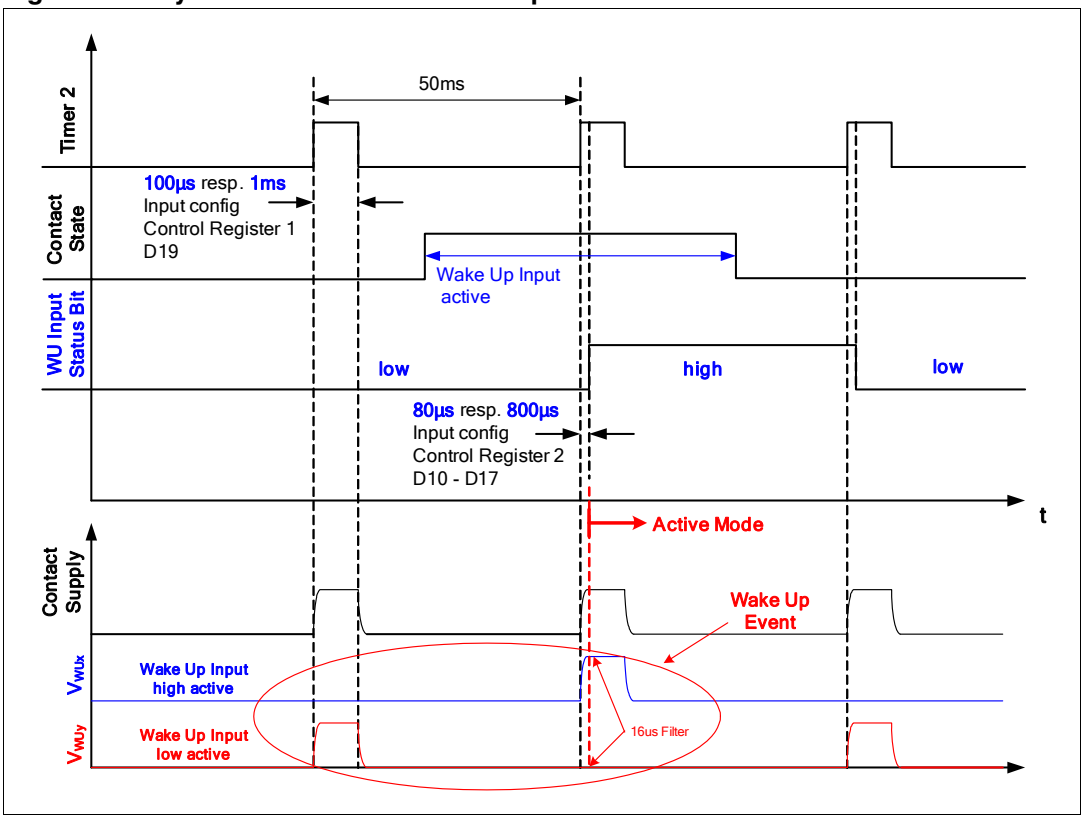
For leakage current limitation, the current source configuration is recommended for active low contacts and the current sink configuration is recommended for active high contacts.

Figure 13. Cyclic contact sense: contact connection



To use the cyclic sense the contact has to be powered by any HS driver (Out1-4 or Out_HS). According to the description in the chapter “prepare for standby”, the output has to be set to Timer 1 or Timer 2 mode to be able to power the contact in standby mode. The timer 2 is intended for contact sense, but timer 1 can be used as well if the timer 1 settings are appropriate. The cyclic sense of the contact is based on the selected timer settings. The WU input which is used for contact sense must have the filter configuration corresponding to the used timer settings (period and On-time).

Figure 14. Cyclic contacts sense: wakeup events



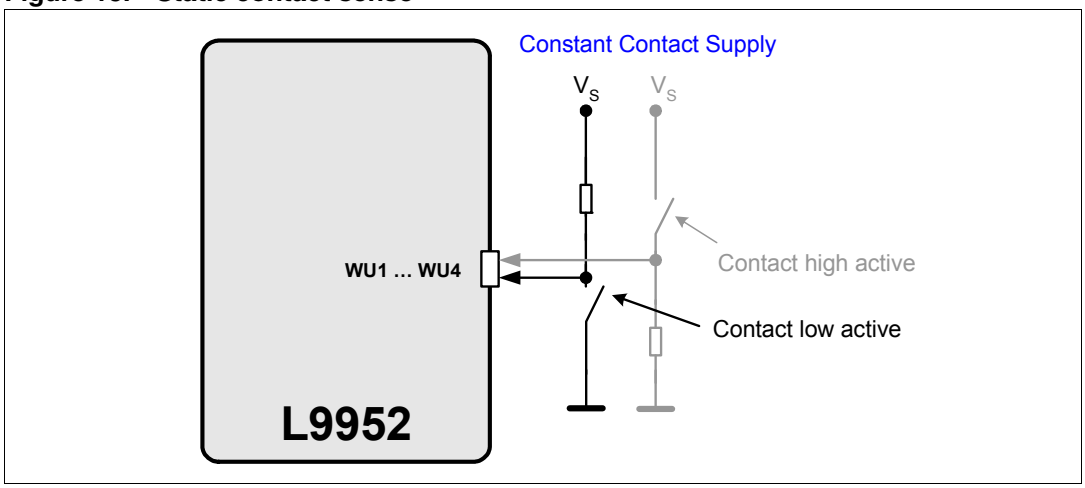
In case of improper configuration of the HS output and the WU input filter, the wakeup functionality from standby mode is not working or a transition to standby mode is not possible, because of immediate wakeup.

If the configuration is correct and the device is switched to standby mode, during every timer ON time of the selected timer, the contact supply is activated and the contact status is evaluated at the WU input. The input signal is filtered (80us blanking, followed by 16us filtering in typical conditions) and the wakeup is processed in case that a level change on the input is detected compared to the previous qualified value.

6.2 Static contact sense

In static contact sense configuration, the contact has to be powered by an external power source (see *Figure 15.*).

Figure 15. Static contact sense



The big advantage of this mode is the extremely low power consumption of the L9952GXP (typically 7 µA). If only closing high active or low active contacts are used, the complete power consumption of the contact sense is lower than for cyclic sense. To achieve the low power consumption, proper configuration of current sink or current source at the wakeup inputs has to be set for each WU input. **For leakage current limitation, current source configuration is recommended for active low contacts and current sink configuration is recommended for active high contacts**.

For this mode the static filter has to be selected on each dedicated WU input. If the static filter is configured, the input is monitored with a 64us filter typical. If any status change is detected at the input, the L9952GXP enters the wakeup procedure and the value is stored in SR0 bits 13 (WU1) to 16 (WU4). Details of the system wakeup by static contact sense are shown in the next figures. The first diagram shows the signals for active High contacts and the second diagram for active low contacts.

During static contact sense, it is also possible like for cyclic contact sense to use the WU inputs with a configured filter synchronized with Timer 1 or with Timer 2. The contact value will be evaluated correctly, but only during timer ON time. The wakeup functionality will also works, but the L9952GXP core current consumption is increased as in cyclic mode.

Figure 16. Static wakeup by active-high contacts

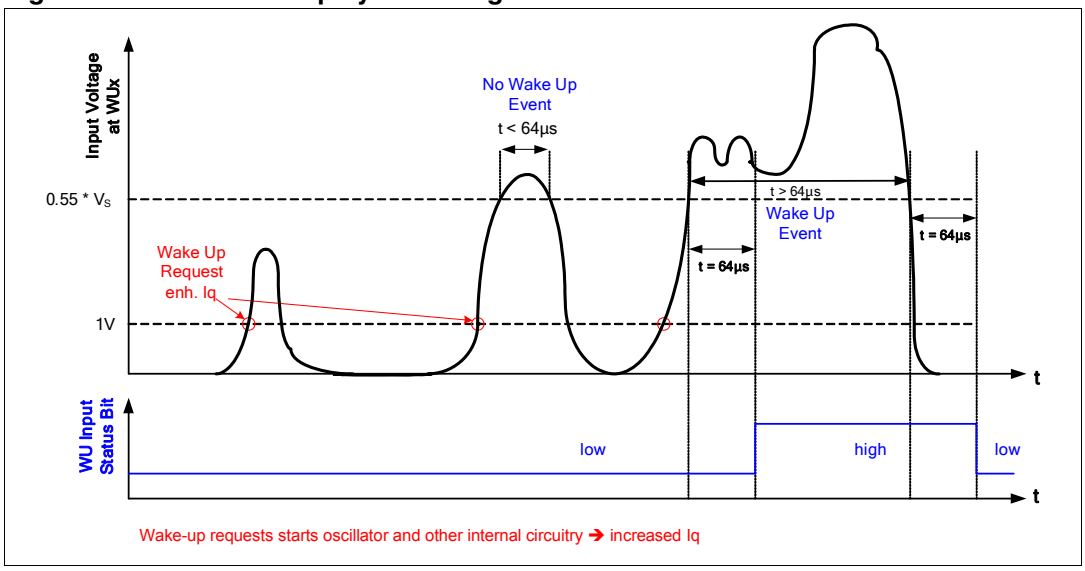
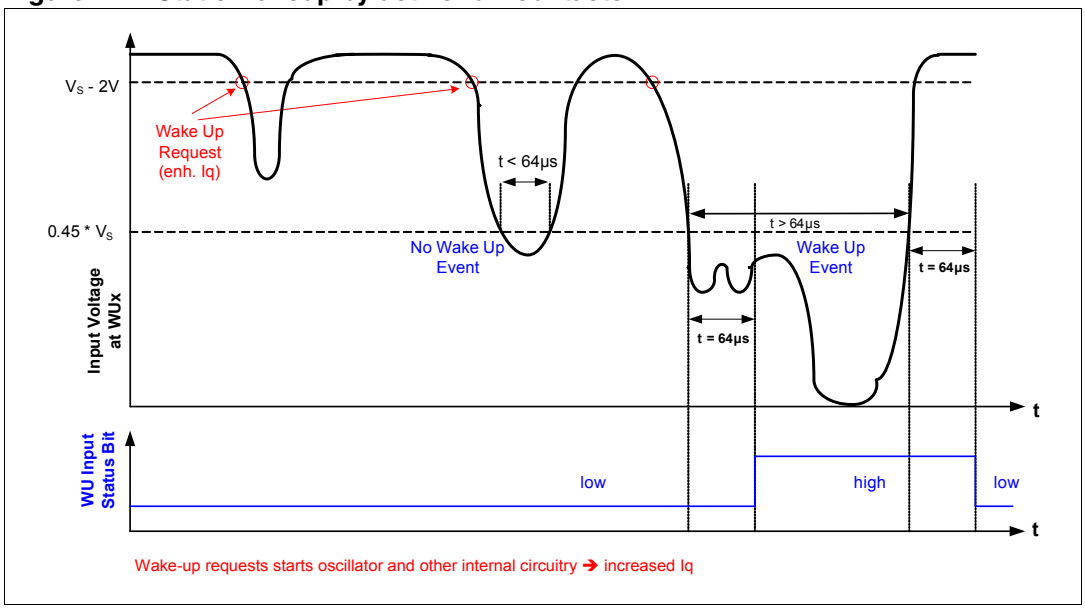


Figure 17. Static wakeup by active-low contacts



7 Diagnosis

L9952GXP provides a wide range of diagnostics information through the SR0 and SR1 status registers. These diagnostic flags are related to output drivers, junction temperature, voltage supply monitoring, and wakeup inputs.

The first diagnostic to be performed is the initialization diagnosis. But several additional have to be periodically monitored to check the status of the application and take corrective action if needed. These diagnostic flags are related to:

- Output diagnosis (open-load / over current)
- Chip junction temperature (TW, TSD1 and TSD2)
- Vs monitoring (Over-voltage / Under-voltage)
- V1 monitoring (short circuit, number of restarts after TSD2 and voltage glitch)
- V2 monitoring (short circuit and voltage glitch)
- Wakeup input sources (CAN, LIN, WU Contacts, OL Contacts and SPI)
- Watchdog trigger and successive watchdog failures.

7.1 Initialization diagnosis

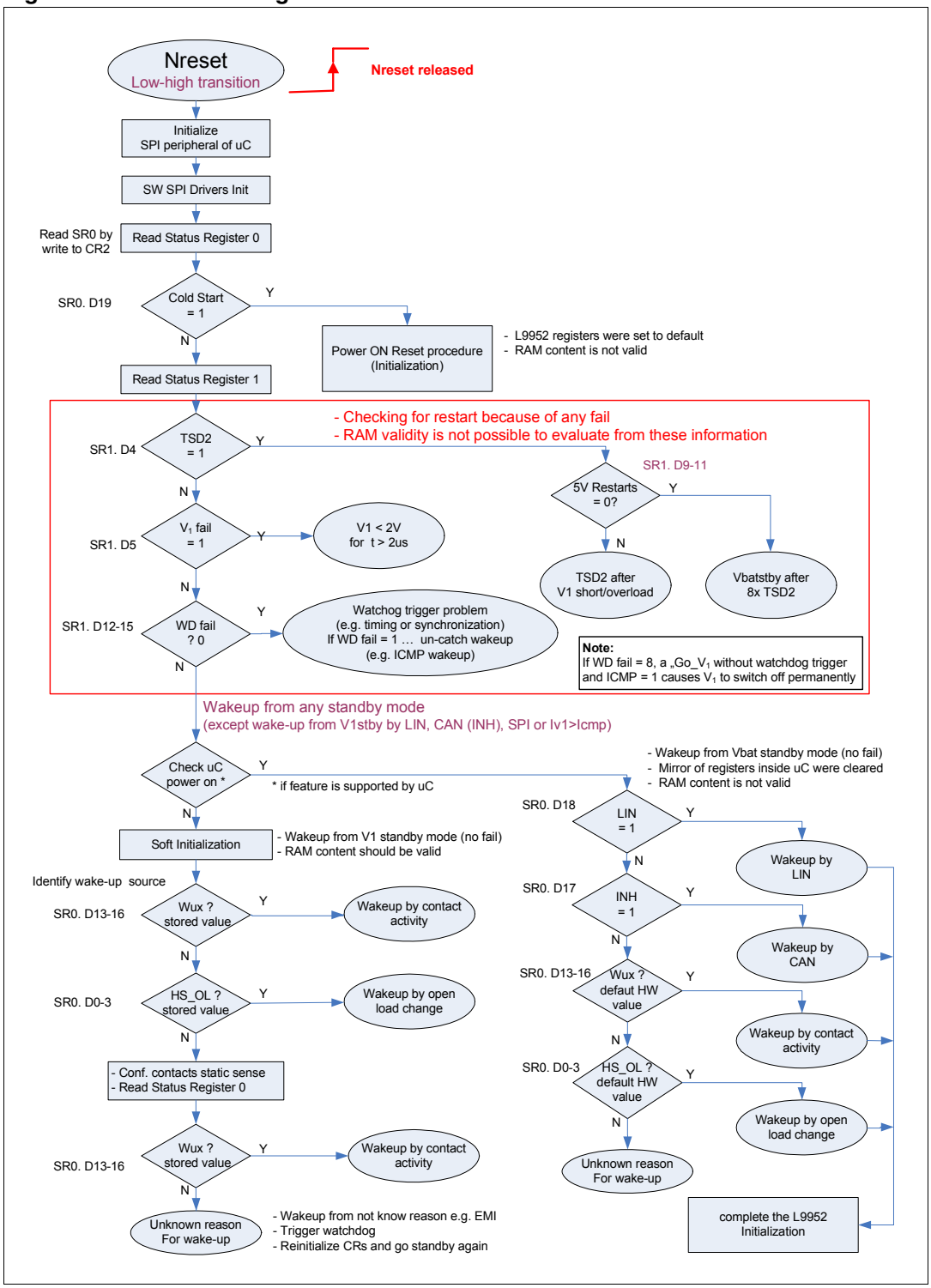
The following flowchart (*Figure 16.*) describes in details the recommended initialization procedure. Additionally the dedicated Software routine has been inserted in the appendix.

At power-on, when Vs voltage is applied, the V1 voltage supplying the microcontroller is immediately turned on thanks to its very fast transient response and the NReset signal is generated. Note that no external electrolytic capacitance is needed.

At that time, the microcontroller does not know whether a power-on or a wakeup event from any standby mode occurred. Finding the origin of microcontroller restart is the topic of this initialization diagnosis. Typically microcontroller power supply - connected to V1 voltage regulator - is switch off in power off state, Vbat_standby mode and in the case of a hard restart after several successive fails (e.g. 7 successive watchdog fails).

The microcontroller is restarted by NReset generation after a wakeup from V1 or after a watchdog fail. During the power-on diagnosis the right reason of the microcontroller restart should be identified and action taken regarding the previous state. Since after NReset generation or V1 turn-on the watchdog start with long open window, all this power-on diagnosis has to be done before the long open window expiration (65ms typical), otherwise the power-on diagnosis will have to re-started form scratch without any diagnosis on the restart reason or Cold Start event.

Figure 18. Power-on diagnosis: detailed flowchart



7.1.1 Cold start diagnosis

After power-on, when the Supply Voltage Vs passes the Power-On-Reset ***(POR)*** threshold (3,8 V typical), the ***"cold start"*** *bit (CR0 bit 19)* is latched (see *Figure 19.*). Consequently all SPI registers are initialized to their default value. Only a power-on event latches the cold start bit - It is NOT set after waking-up from any standby mode or after any failure occurrence (Thermal Shutdown, V1 Fail, WD Fail…).

Only the first SR0 read access immediately following a power-on will return the cold start flag. This bit is cleared after the first complete SPI frame completion, precisely when the CSN signal is relaxed (rising edge). A complete SPI frame means that 24 SPI_CLK pulses were transmitted while SPI_CSN signal was low. In case of an SPI communication Fail – e.g. a short on SPI_CLK signal – the cold start bit is hold at 1 until the next SPI frame completion.

Note: If your application needs to monitor the cold start information or identify the wakeup event source, a SR0 read access has to be performed immediately after any power-on or NReset events. It is recommended to choose a CR2 write access rather than a CR0 write access for reading the SR0 content:

- *In case of a wakeup from V1 or Vbat_standby mode, a CR0 write access overwrites the predefined Trigger as well as the V2 and the outputs configurations whereas a CR2 write access has a smaller influence at application level and by the way is a safest procedure depending on the targeted application.*
- *Naturally and depending on the targeted application, it is also possible to configure the outputs directly after an NReset generation.*

7.1.2 Vs power supply: under/over-voltage detection

Vs under/over-voltage diagnosis flags can be monitored after power-on and then periodically during active mode. Two Status flags are available:

- The under-voltage flag ***UV*** (SR1 bit 1) signals that Vs dropped below the under-voltage threshold (Vsuv) e.g. 5.5V typical.
- The over-voltage flag ***OV*** (SR1 bit 0) signals that Vs reached the over voltage threshold (Vsov) e.g. 20V typical.

After any under/over voltage event, all HS, LS and LIN outputs (OUTx, RELx, LIN) are switched to high impedance state by default (load protection). If the under/over-voltage condition disappears, an automatic recovery feature (active by default), makes all outputs recover their previous state (according to CR0 settings).

Additionally, for security concern, two control bits have been implemented:

- The automatic recovery feature can be disabled with the $\boldsymbol{V_{S\ LOCK\ Out}}$ bit (CR2 bit 4). If this bit is set, all outputs will remain off even after over/under-voltage recovery condition has disappeared, until the status bits SR1 bit 0 and SR1 bit 1 are cleared by a CLR control command (CR1-21).
- The $\boldsymbol{LS\_{}_{OVUV}}$ bit (CR2 bit 19) enables to control separately the low-side outputs behaviour (REL1, REL2) in case of under/over-voltage.

Note: 1 If the under-voltage bit is latched but not the cold start one, then the Vs voltage is in the range of 3.8V to 5.1V. In that particular case, the L9952GXP configuration remains valid: Its internal SPI registers are not reset and its outputs drivers remain unchanged.

2 V1 and V2 voltage regulators remain on after a Vs over-voltage.

7.1.3 $V_{1,2}$ voltage regulators - failing supply detection

Depending on the application, it could be mandatory, at the upper application layer, to monitor the subsystem microcontroller RAM consistency and if needed to take corrective actions. The ***V_{1fail}*** (SR0 bit 5) and ***V_{2fail}*** (ST1 bit 6) flags are dedicated for this purpose. The *Figure 19.* illustrates V1 or V2 voltage regulator behaviour under specific conditions.

The following two scenarios have to be considered:

At initial turn-on of $V_{1,2}$ voltage regulators

If a short to ground is detected ($V_{1,2}$ < 2V) for at least 4ms then the V_{1fail} respectively V_{2fail} flag is latched (SR1 - bits 5/6) and dedicated regulator is switched-off to avoid thermal cycling at static short circuit.

In case of a V_{1fail} event the L9952GXP automatically enters Vbat_standby mode and all its outputs are turned Off. The re-activation or wakeup of the device can be achieved with signals from the CAN, LIN, $WU_{1..4}$ or SPI. The current leakage origin can then be found by reading the SR0 and SR1 status registers.

In case of a V_{2fail} event the voltage regulator is purely switched-off. Additionally the ***SHT5V2*** flag is latched (SR0 bit 12) to indicate a V2 short. A clear command is required to re-activate V2 (CR0 bits 17/18).

During active mode

In case of $V_{1,2}$ voltage regulator drop below 2V for at least 2 µs, the $V_{1,2\ fail}$ bits are latched (SR0 - bit 5 for V_{1fail} and bit 6 for V_{2fail}). These under-voltage events are typically due to electromagnetic disturbances. When the V_{1fail} or V_{2fail} have been latched, the microcontroller RAM consistency cannot be guarantied anymore and the upper application layer has to take the adequate corrective action.

Note that the V_{1fail} and V_{2fail} failing bits have first to be cleared by a SPI write access on CLR bit (CR1 bit 21) before re-activating the voltage regulators.

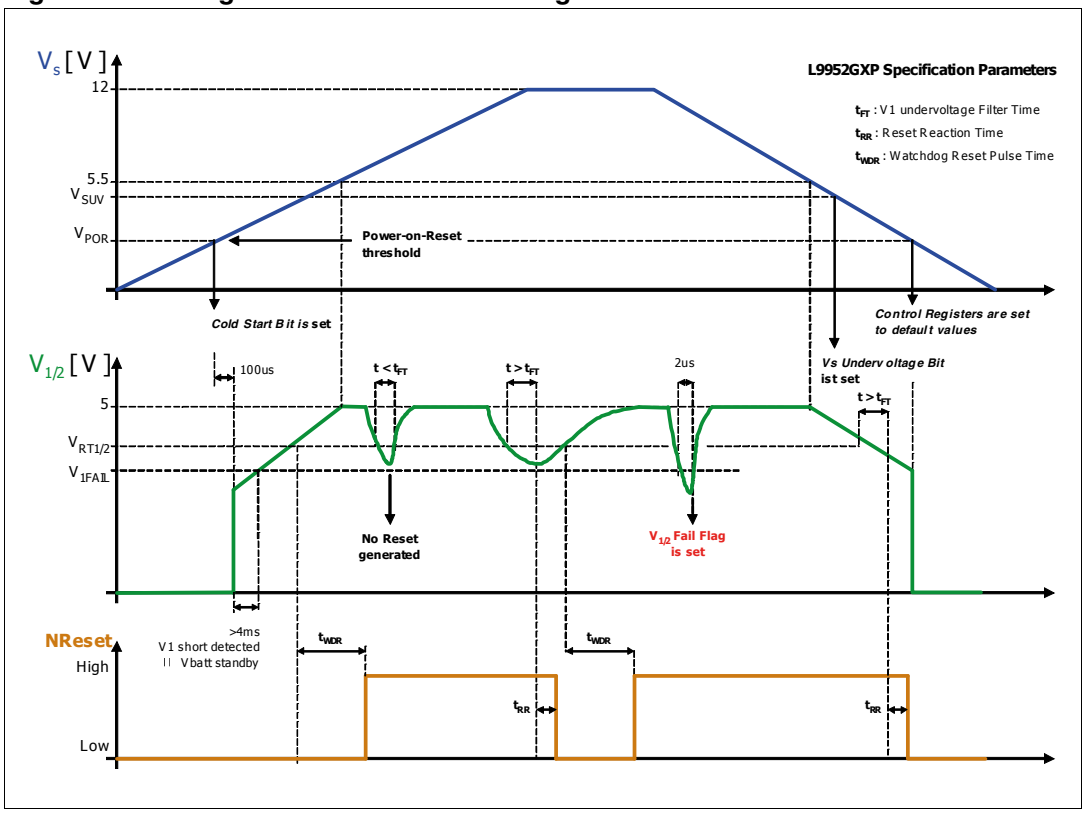
Note also that during active mode, if the voltage drop is below V_{rth} for at least 8µs (typical) the NReset is immediately forced to low. This is one of the root events that can trigger the NReset generation. The other events will be developed within the next chapter.

7.1.4 NReset generation

As we have seen any short disturbance on the supply lines can affect the Memory content of the microcontroller and bring the application out of control.

This is why an NReset signal will be generated as soon as the disturbance on the supply lines will reach the specified range and as soon as it will remain during the minimum specified period. The following figure illustrates this behaviour.

Figure 19. Voltage thresholds and NReset generation



7.2 Output drivers diagnosis

Open load flags are available for HS outputs Out1-4 and Out HS. These flags are set immediately when an open-load condition is detected during output switch-on and cleared immediately when the open-load condition disappears and the corresponding output is switched on. If an output is configured to timer mode, the open-load is detected during ON time only. So the flag is set and cleared periodically according to the timer settings. The same behaviour will be observed if an output is configured for PWM mode: The open-load flag is set only during ON time of the output.

Over current flags are latched when an over current is detected on Out1-4, Out_HS or Rel1-2. The output where the over current is detected is immediately switched off and stays off, until the status flags are cleared by setting the CLR bit of CR1-21.

Additionally the Out_HS behaviour is configurable after an over-current event. By default, the auto-recovery bit ***O_HS_REC*** (CR2 bit 5) is disabled and the output is switched off. If auto recovery is enabled, the output is restarted automatically after an output over-current shutdown. The auto recovery filter time is 400xTosc.

7.3 Junction temperature diagnosis

Temperature control is a protection feature to avoid thermal destruction of the device. If the chip junction temperature exceeds 130°C, the temperature warning TW bit is set in SR1.2. Additional increasing of the junction temperature over 140°C sets the Thermal Shutdown 1 bit and all outputs are switched off, except the V1 which remains ON. If the temperature increases over 155°C the Thermal Shutdown 2 bit is set and V1 is switched off for 1s. After 1s the V1 is switched on again. If the temperature reaches TSD2 8 consecutive times (each within 1 minute), the L9952GXP is automatically forced into Vbat_standby mode. Wakeup is possible by any wakeup event (according to the configuration in the CR).

7.4 Global error flag

The first two bits of any SR0 or SR1 read access (read back by addressing CR0, CR1 or CR2 control registers) contain the **global error flag**.

The **global error flag is a logical OR** of all error flags related to power supply signals and all error flags related to over-current on output stages.

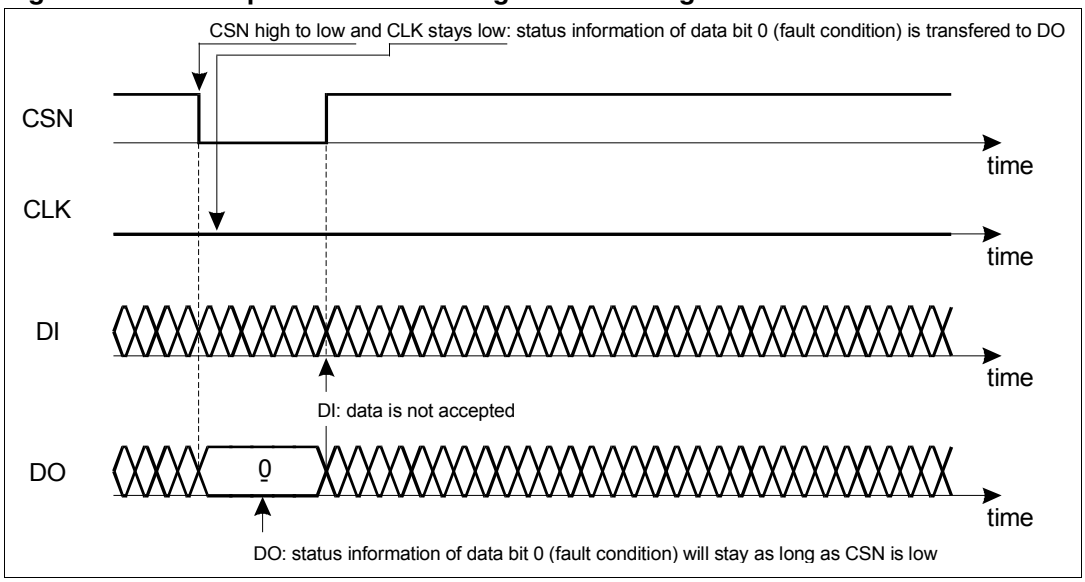
- The power supply errors flags are: V1fail V2fail, TW, TSD1, TSD2, UV and OV – e.g. 7 possible error flags.
- The over-current error flags on output stages are: HS1..4OC, HSOC, Rel1_OC, Rel2_OC and SHT5V2 - e.g. 8 possible error flags.

Note: The global error flag can be read on DO line by pulling CSN line from high to low while CLK line is forced low. If DO line is low no errors has been latched, whereas if DO is high, the SR0 and SR1 registers will have to be read to determine the error(s) flag(s).

This feature, showed in *Figure 20.*, enables a very quick evaluation of the global error flag without transmitting a complete SPI frame (24 CLK Pulses) and without overwriting the control registers. (CLR bit write access could have masked a failing flag.)

It is recommended to use to feature after any NReset event.

Figure 20. Fast capture of L9952GXP global error flag



Note also that an SPI frame consistency is permanently checked through SPI clock signal. Every frame must contain 24 bits, e.g. 24 clock low-to high transitions while CSN is low, otherwise the SPI frame is ignored.

7.5 Periodical monitoring

L9952GXP device status information is stored in 2 status registers. The SR0 is read with every write to CR0 or CR2. The SR1 is read by writing to CR1.

Most of the flags used for diagnosis purpose after “power-on” or after “NReset generation” have been described in the previous sections. But independently of diagnosis procedures, the following flags should be evaluated periodically during active mode:

- Output open-load and over current - periodically check if output is on. The timing is application specific, but recommended is first check after 64 us after output turn-on.
- SHT5V2 – short circuit at V2 voltage regulator. The flag is set if V2 is below 2V after 4ms after turn-on. The voltage regulator 2 is switched off in this case in order to avoid thermal cycling of the device. The voltage regulator is turned back on as soon as the SHT5V2 bit is cleared by setting the CLR bit in CR1.
- V1 fail / V2 fail – Flag indicating fail of voltage regulator for at least 2 us (threshold is 2V). This flag should be periodically checked - at least after each write to CR1.
- Thermal warning / thermal shutdown 1 – flags indicating increased chip temperature, e.g. over current on some output or voltage regulators. Timing of these flags evaluation is depending on application needs.
- Over Voltage / Under Voltage – flags indicating Vs is out of operating range. Recommended is a periodical check of these flags to avoid improper system behaviour caused by to Vs over/under-voltage.
- TRIG – indicates the current polarity of the WD trigger bit. This information can be useful after wakeup form V1_standby, to set the proper trigger bit polarity for the first trigger operation. It is only useful after wakeup from V1_standby when no NReset was generated. In case of a NReset generation, the trigger bit is always set to ‘0’ and the WD refresh has to start with “1”. Nevertheless after wakeup from V1_standby without any NReset, the microcontroller memory content should contain the valid trigger bit polarity. In this case, the evaluation of this flag is not required. In all other cases the polarity is set to ”0”.

8 Standby modes

The L9952GXP can be operated in two different standby modes Vbat_standby and V1_standby. The main difference between these two modes is that in Vbat_standby the V1 voltage regulator is switched off and the microcontroller is not powered whereas in V1_standby the voltage regulator V1 remains in low power mode in order to preserve the microcontroller memory content and allow external event-driven fast start-up to check additional contacts or perform other periodic tasks. The supplied microcontroller has to reduce its current consumption below the current threshold Icmp_fall (e.g. switch to HALT mode).

The cyclic contact sensing feature can be configured in any standby mode.

In all standby modes all HS and LS outputs are disabled, except the HS outputs configured in timer mode. Dig_Out outputs can be also active, but not in all modes. Details are described in the next chapters.

8.1 Preparation before entering standby modes

As we already introduced, the L9952GXP supports two low power modes:

- V1_standby mode - ***V1_standby*** for supplying a microcontroller in low current mode.
- Vbat_standby mode - ***Vbat_standby*** for minimizing the application current consumption.

Entering a standby mode means that a future and unpredictable wakeup event will make the L9952GXP exit this standby mode.

8.1.1 Wakeup sources

The wakeup sources have to be configured (enabled/disabled) prior entering any standby modes in order to ensure the desired wakeup procedure while avoiding unwanted wakeup events. But not all wakeup sources can be disabled.

The L9952GXP provides the following wakeup sources:

- ***CAN*** bus activity (through inhibit pin ***INH***)
- ***LIN*** bus activity
- ***SPI*** bus access (first rising edge on CLK after CSN is pulled low)
- Increasing current at V1 voltage regulator exceeding threshold Icmp_rise
- Wakeup inputs ***WU1..4*** status change (static or cyclic external contact sense)
- High-Side ***Out1..4*** open-load status change

The CAN (INH signal) and LIN wakeup events are always active in both standby modes and cannot be disabled. The SPI wakeup event is only possible in V1_standby mode and cannot be disabled.

The WU1..4 wakeup events related to the external contact sense can be disabled (CR1 D0-D3) so that the open-load status events on the High-Side Output stages (CR1 D4-D7).

Any unused wakeup inputs (WU1-4) should be disabled and connected to GND. It can eventually be left open if no PCB trace is connected to the pin. It is recommended to configure unused inputs as current sink in standby modes (CR1 D8-D11 default configuration).

It is also recommended to disable the wakeup by open-load status change on High-Side outputs Out1-4 if this event is not used.

8.1.2 Contact sense flowchart

Before entering one of standby modes from the active mode (Write access on CR0 bits 20 and 21), a preparation for standby procedure has to be followed. Several successive actions are required in order to ensure a safe wakeup and allow a successful evaluation of the wakeup source.

The preparation for standby can be divided in tree main steps:

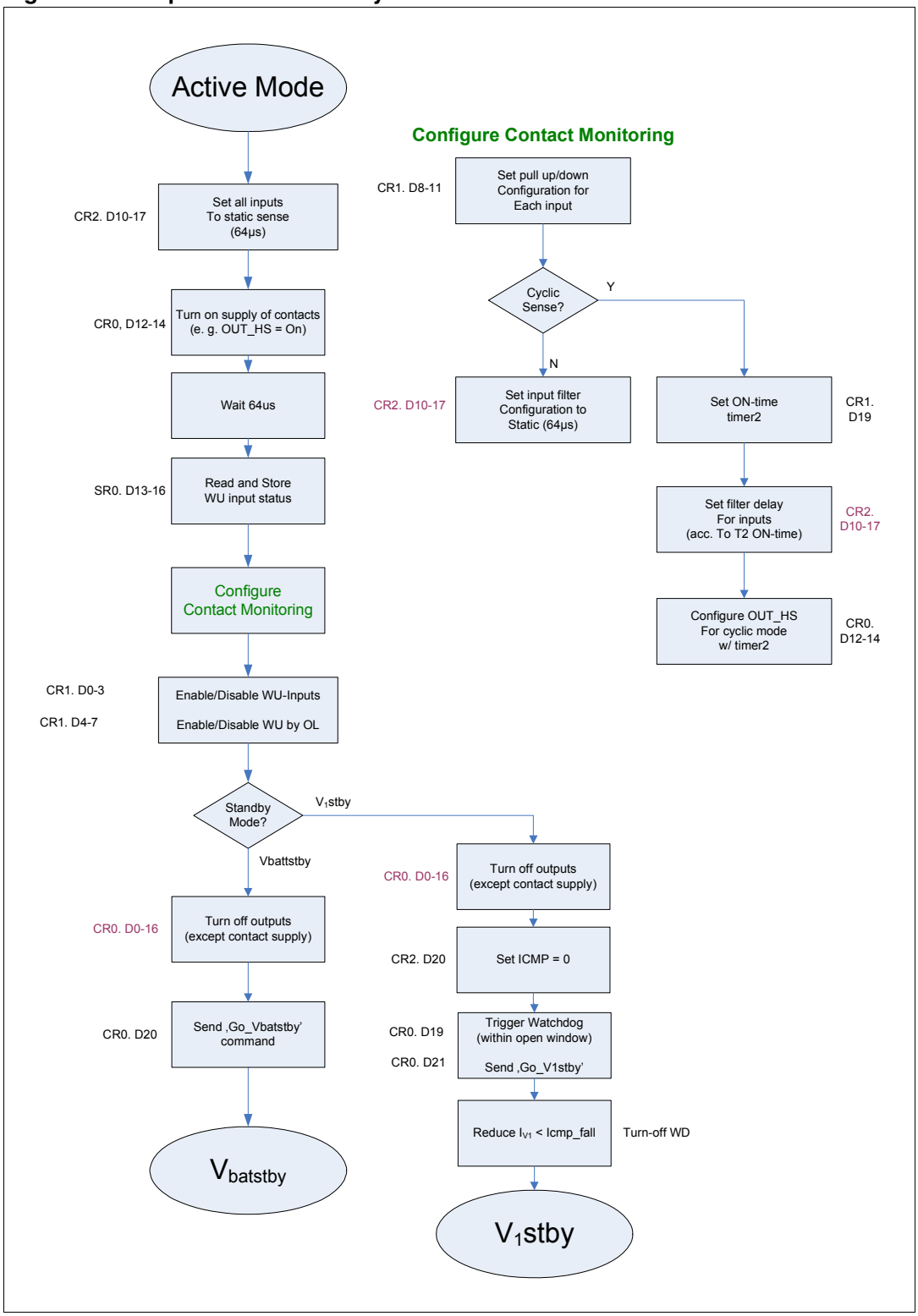
- Read and store contact State (Static Supply of the contact - filtering - capture)
- Configure contact sense (static sense / cyclic sense with timer settings)
- Enter standby mode (turn-off outputs / trigger watchdog)

The next figure shows the detailed flowchart of a typical standby mode preparation.

The details and internal actions of these steps are described in the following section.

The corresponding software code can also be found in the *Appendix A*.

Figure 21. Preparation for standby flowchart



8.1.3 Read and store input status

If the wakeup functionality by external contacts is required, the inputs have to be configured to the proper mode. The wakeup condition is a changing status at the input, so it is possible to connect high or low active contacts with closing or opening functionality. For this reason, the contact status corresponding to the inactive contact position has to be read and stored, before the L9952GXP is switched to standby mode.

The sequence how to store the contact state is detailed in the flowchart in *Figure 44.*. In Active mode the WU inputs are set to static contact sense. If the contact will be read in cyclic mode and is powered by an HS output, the corresponding HS output has to be set to the permanent ON mode. Then wait at least 64us to allow settling of the voltage level and read the contact state from SR0. The contact status should be stored into microcontroller permanent memory to allow the identification of the contact at the origin of the wakeup. The identification can either be done by comparing the previous stored value and the one after waking-up or by comparing the new value with a predefined inactive status value, stored also in microcontroller permanent memory.

Anyhow it is **always recommended** to capture the contact status before going to any standby mode to get sure that the wakeup occurs in case of contact state change.

8.1.4 Configure inputs

When the present contact value is caught and stored, the contact sensing has to be set to the configuration which is used in standby mode. During the entire procedure, the value at the WU input has to be maintained. Otherwise, the contact value caught by the internal logic can be overwritten. For this reason the exact setting sequence has to be followed.

The WU input configuration is different for each operational mode. In Active mode an internal pull down resistor of 200kOhm typical is active.

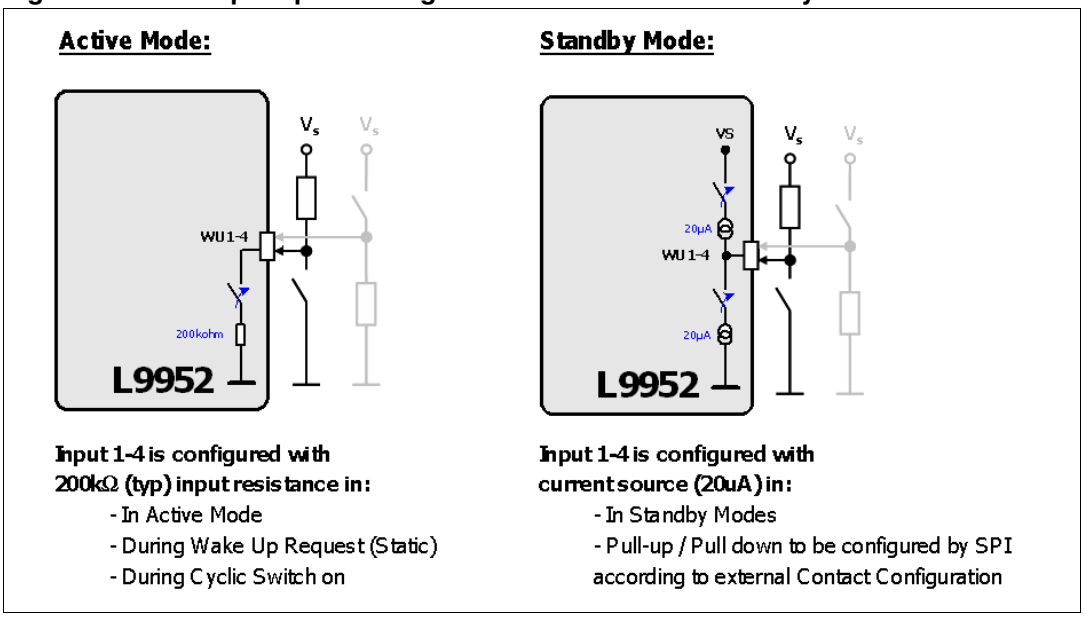
In standby modes the input configuration depends on the selected filter configuration.

For WU input filter in Static Sense configuration, a current sink or a current source can be configured on each WU input (CR1 bits 8 to 11). The right configuration depends on the contact type connected to the WU input. In case of a wakeup request during static contact sense (i. e. WU input voltage is above 1V or below Vs-2V) the 200 kΩ pull-down resistor is activated (same configuration as in Active mode).

In the case of a cyclic sense the WU input configuration is variable. During timer ON Time, when the contact is checked, the internal pull down 200kOhm is configured (same configuration as in Active mode). During timer Off Time, the current sink or the current source can be chosen in CR1.

The configuration should be done according to the connected contact structure in order to reduce additional power consumption as well as reduce WU input leakage current if the contact is not powered and the input is floating.

Figure 22. WU inputs pins configuration for active and standby modes



If the contact is sensed statically in Active or standby mode, the contact has to be powered by an external source and the type of current sink or current source should be set according to the contact configuration (pull-up/current source for active low contacts; pull-down/current sink for active High contacts). The WU filter configuration for static sense is the same like for Active mode, so it is not required to change it before transition to standby mode with static contact sense. More details are described in chapter standby mode/ Static Contact Sense.

For the cyclic contact sense, the configuration sequence is more complex. The following sequence of settings must be obeyed:

- Configure the contact for static sense
- Read and store the contact value
- Configure the Timer to be used for the contact sense
- Configure the input current sink / current source according to the external contact structure.
- Change the input filter according to the selected timer settings
- Change the output used for the contact supply to the corresponding timer mode (until now the HS output associated to the contact supply has to be switched ON)

Last step (change contact supply to cyclic mode) can be done together with the Go_standby command, but only if the configuration sequence was kept. If the configuration of the cyclic sense was made in another order, it is required to wait for a time longer than timer period before to go to standby to be sure that the contact status was captured and correctly stored in the internal logic register. The WU input status is captured during timer-on time if cyclic sense is selected. If cyclic sense is configured correctly, the contact value will be stored only during this corresponding timer on time.

8.1.5 Set ICMP = 0

For safety reasons this bit should be set to 0 when the V1_standby mode will be used. If this bit is set to 1, the V1 current comparator is disabled and the WD deactivated immediately after transition to standby (regardless of the current consumption of the microcontroller) and is not activated when the current at V1 exceeds the threshold Icmp_rise.. This current comparator is used to start the watchdog after a wakeup of the microcontroller by any other source. Furthermore, it prevents the microcontroller from running without supervision by the WD after transition to V1_standby mode.

(paste) Increasing current at V1 voltage regulator exceeding threshold Icmp_rise (WD is started and regulator enters high current mode, i.e. increased quiescent current; the device remains in standby mode)

8.1.6 Turn-off outputs

All outputs which are not used in standby mode for cyclic functionality, e.g. LED flashing or cyclic contact supply, should be switched off before transition to standby mode. If any outputs are configured to ON or PWM mode, they are switched off in standby mode. But immediately after wakeup these outputs are recovered to the last state (i. g. the output control settings in CR0 are not cleared in standby). To avoid unwanted turn-on of outputs after wakeup, the outputs should be switched Off before going to standby mode.

8.1.7 Trigger watchdog

When V1_standby mode will be entered, the last action before turn to standby mode should be a trigger of the Watchdog. After transition to V1_standby mode, the current consumption has to be below the threshold Icmp_fall. As soon as the bit Go_V1_standby is set in CR0, the L9952GXP enters the standby mode. However, the WD keeps running until this current threshold is reached. If the watchdog open window expires before the current decreases under the threshold, the watchdog fails and the microcontroller is reset, which prevents the system from going to standby mode. To get the maximum time to reduce the current consumption of the microcontroller the watchdog should be triggered directly before the 'Go_V1_standby' command (i. e. the transition to standby should be synchronized with the WD trigger procedure).

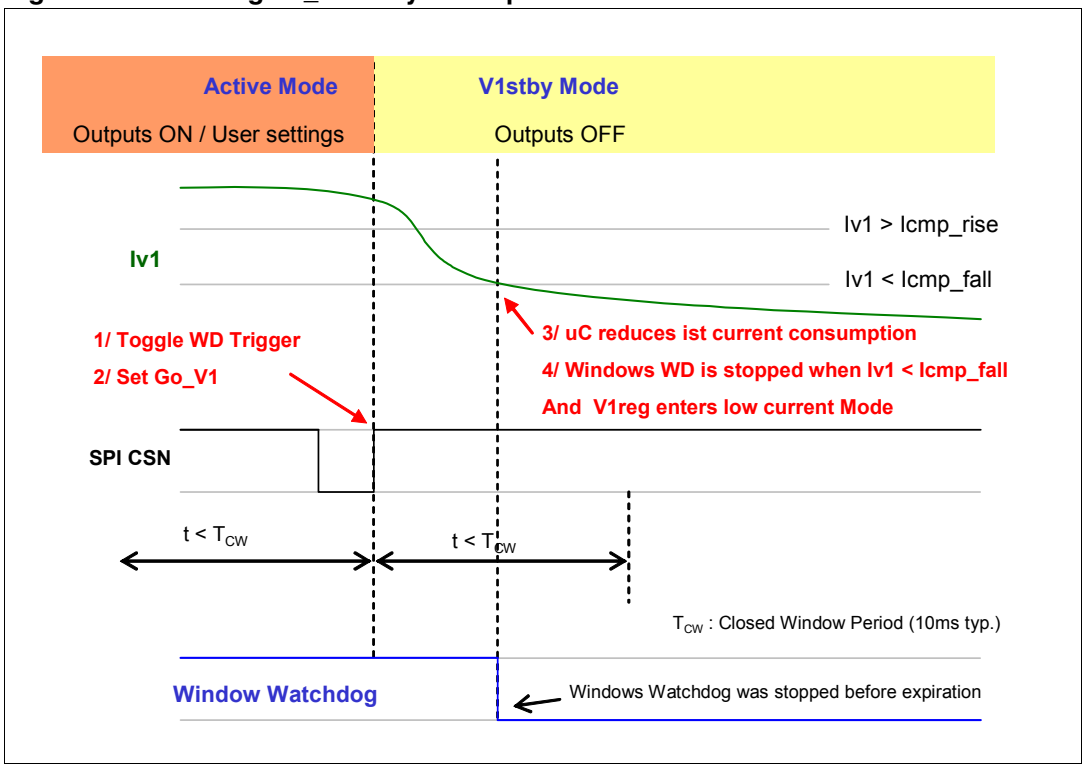
A 'Go_V1_standby' command with a WD failure counter 0 and a 'Go_V1_standby' command causing a WD failure is not allowed.

8.2 Go to standby mode

Go to standby mode is possible after previous initialization as described in chapter "Prepare for standby". Switching to Vbat_standby can be done at anytime just by setting Go_Vbat bit (CR0-D20). After the rising edge of the CSN ending the SPI frame transmission the device is switched to Vbat_standby and V1 is turned Off.

Switching to V1_standby is a bit more complex and illustrated in *Figure 23.*:

Figure 23. Entering V1_standby mode procedure



First the “preparation before standby” should have been done. Then the application micro should wait (thanks to internal synchronized timer) for the next open window of the WD. As soon as the open window is detected, the watchdog has to be triggered and V1_standby mode can be entered by setting Go_V1 bit (CR0-D21). Until the next watchdog open window expires, the microcontroller has to reduce its current consumption below the Icmp_fall threshold current (e.g. the microcontroller has to turn to HALT mode or equivalent).

At that time the watchdog trigger is stopped and the V1 voltage regulator is turned to low-current mode.

In case the Icmp_fall threshold current is not reached before the watchdog expiration a watchdog failure is detected - an NReset signal is generated and all LL92GXP outputs are turned Off.

Recommendation: always trigger the window watchdog simultaneously or just before setting the Go_V1 bit.

8.3 Current monitoring in V1_standby

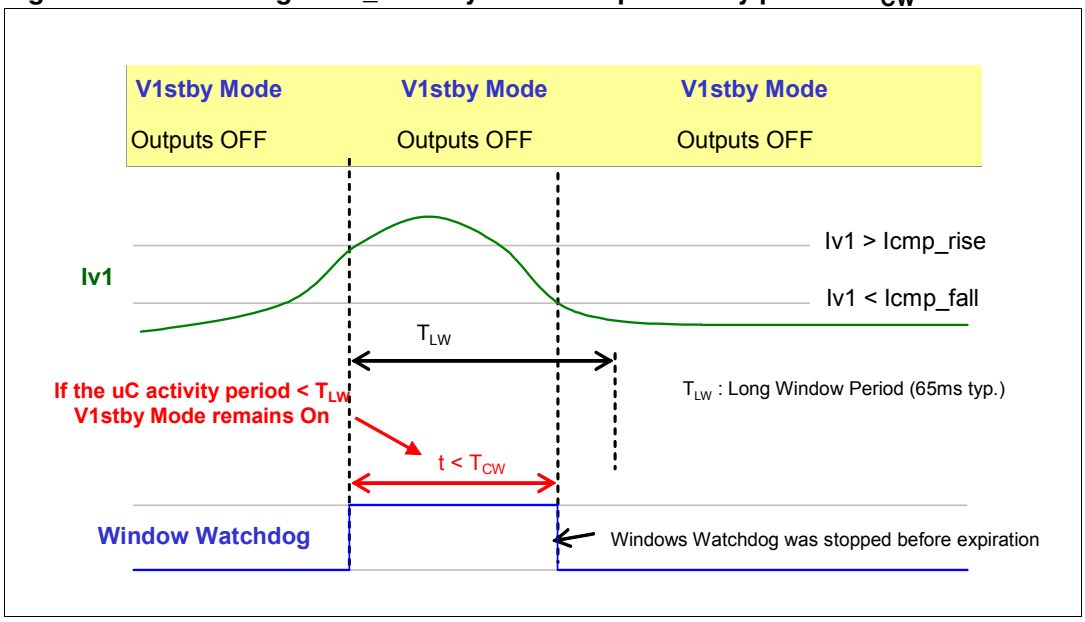
In V1_standby mode, the V1 voltage regulator remains turned On in order to preserve the microcontroller RAM content. For entering V1_standby mode the micro has first to set the Go_V1 bit (CR0 – bit 21) then to reduce its current consumption so that the current delivered by the voltage regulator decreases below the threshold Icmp_fall (approx. 850uA). At that time, the window watchdog generation is stopped and the voltage regulator is automatically turned to low current mode (minimum quiescent current).

The V1 voltage regulator output current is then continuously monitored and in case of a current increase above the threshold Icmp_rise, the regulator is automatically turned to high current mode and the watchdog is started with a Long Open Window (*LOWi)* (65ms typical). This logic activity involves an increase of the quiescent current but the device remains in V1_standby mode and all outputs remain off.

As already described in the “Watchdog Operation” chapter, the microcontroller should trigger the watchdog by inverting the TRIG bit (CR0 bit 19) before the expiration of the LOWi. Note that since no NReset signal was generated, the TRIG bit was not initialized to “0”, and the microcontroller should first read the actual TRIG value rather than directly writing a “1” (which is the expected Trigger Value after power-on or NReset generation).

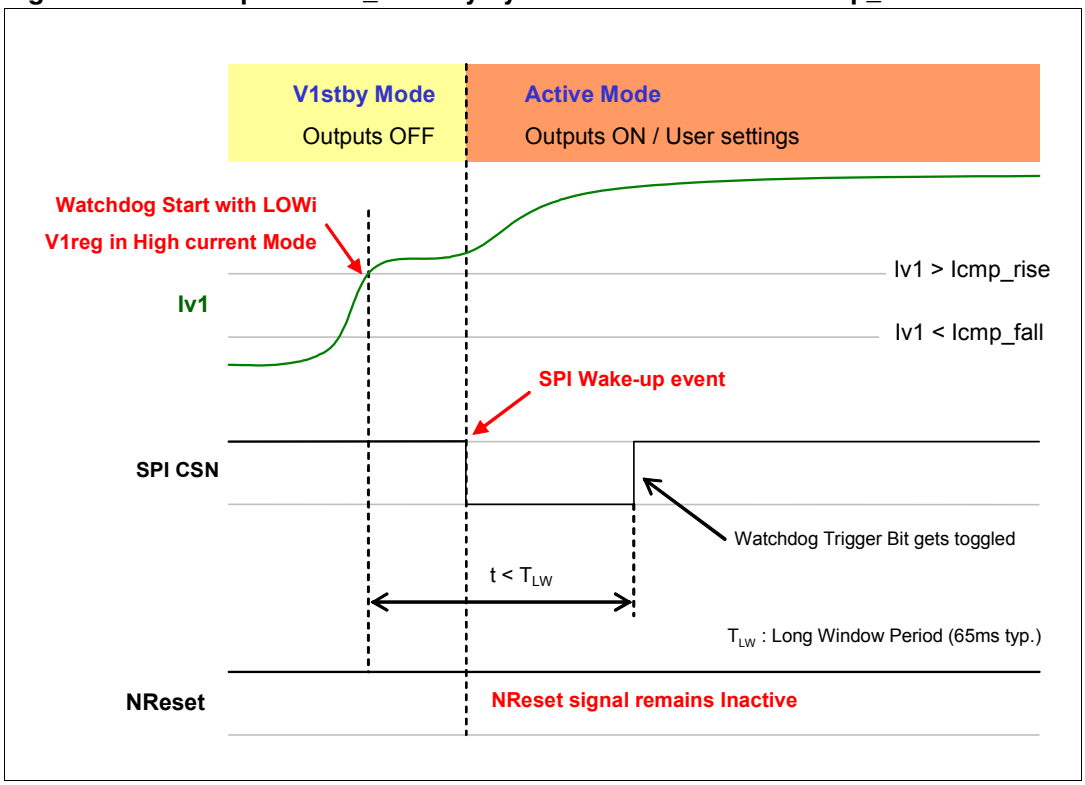
Decreasing the Iv1 current below Icmp_fall and before the LOWi watchdog expiration will turn the device back to V1_standby mode - the voltage regulator will be turned to low current mode and the watchdog will be stopped. This is illustrated in *Figure 24.*.

Figure 24. Remaining in V1_standby in case of µC activity period <T_{CW}



An effective wakeup of the device will occur if the microcontroller increases its current consumption Iv1 > Icmp and then wakes up the L9952GXP by an external wakeup event, for example a SPI access (first rising edge of SCLK signal while CSN is low). Details of such behaviours are shown in *Figure 25.*.

Figure 25. Wakeup from V1_standby by SPI access after Iv1 > Icmp_rise



This feature can be very useful for example in case of INH signal not connected to the L9952GXP. If the microcontroller wakes-up due to an activity on the CAN bus, the L9952GXP will start the watchdog because of the current increase required by the microcontroller. Thanks to the current monitoring feature, the L9952GXP will ensure the supervision of the system.

The V1 current monitoring can be disabled by setting bit ICMP (CR2, D20). This feature may be useful during software development or during flashing in order to disable the watchdog. However, it is not allowed for normal operation, especially if the INH is not connected to L9952GXP, because it is bypassing the fail-safe philosophy of the L9952GXP.

The current, monitored by the current comparator is the output current of the V1 voltage regulator. However, since all digital outputs are also supplied by this regulator, the sum of all the currents has to be considered. The monitored current includes the following current consumptions:

- 5.1 V voltage regulator output
- SPI interface (DO)
- LIN RxD
- NReset
- FSO
- Digital Outputs Dig_Out3 and Dig_Out4

This is a very important note, because it can result in unexpected wakeup events from V1_standby in case Iv1 exceeds Icmp_rise.

For example:

- Any load (about 1mA, e.g. LED) is connected to DO3
- WU3 status looped to DO3 (default configuration)
- Active High contact is cyclic monitored.

In case the contact is activated, the active high status value is looped to DO3. The current of V1 increases above the threshold. But in this case the NReset signal is not generated because the V1 voltage regulator was already turned to high current mode and, as a consequence, the LOWi watchdog was already started: No NReset is generated in this case.

Since the wakeup originally occurred by a status change on the wakeup inputs, an NReset generation is expected by the microcontroller in order to start the reset routine after wakeup. However, NReset is not generated because the watchdog was already started by Iv1 > Icmp

This situation is shown in *Figure 26.*.

Note: This particular problem should not be resolved by disabling the Iv1 current comparator as in this case the system monitoring and the fail-safe functionality cannot be assured anymore. It is highly recommended to choose a system configuration that will minimize the current consumption and, as a mater of fact, will avoid this situation.

Figure 26. Wakeup from V1_standby by WU event after Iv1 > Icmp_rise – No NReset issued

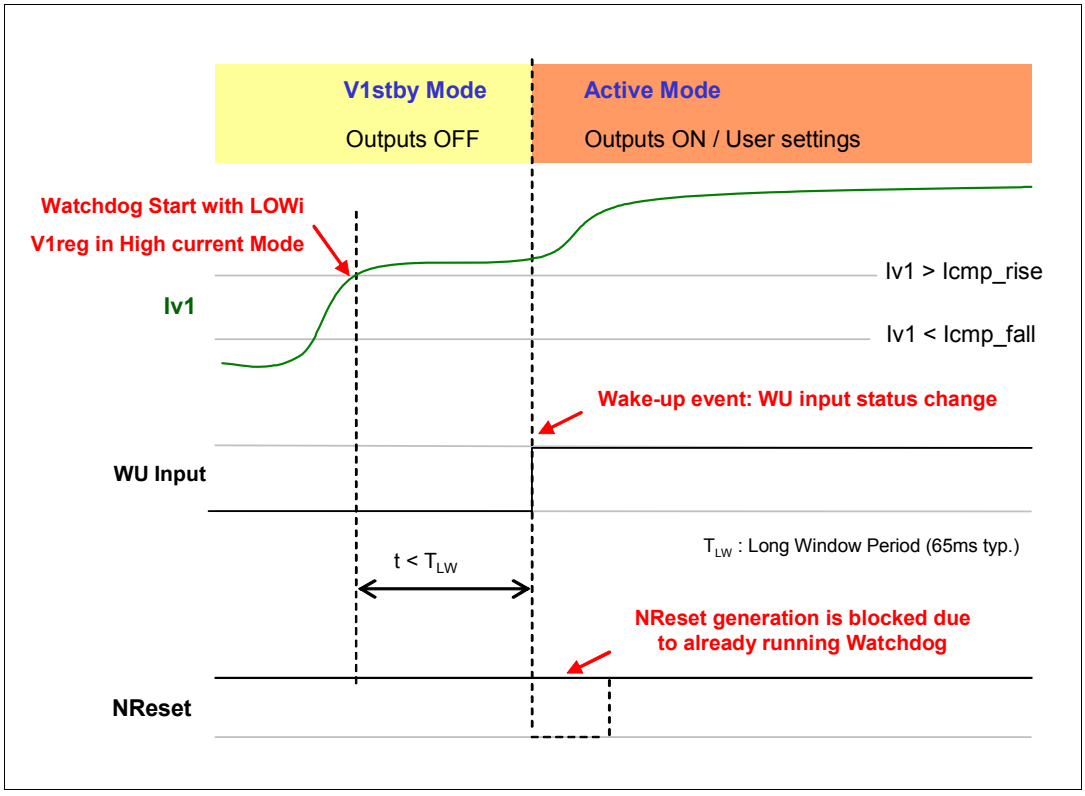


Figure 27. is a summary of the current monitoring feature in one picture: It can be divided in four consecutive phases.

Phase 1

The device is in active mode but is processing the “Preparation before standby” tasks (see the dedicated Chapter *Preparation before entering standby modes* for details). As soon as the preparation tasks are completed, the microcontroller triggers the watchdog and sets the Go_V1 control command (CR0 D21).

Phase 2

This phase starts at Go_V1 control command. The microcontroller decreases its current consumption below Icmp_fall threshold current. At that time, the watchdog is disabled and the voltage regulator turned to low-current mode.

Phase 3

This phase starts when the current threshold increases above Icmp_rise due to microcontroller activity. The watchdog is automatically started with a Long Open Window. But the LOWi expires without been triggered.

Phase 4

This phase starts at watchdog failure. A new LOWi is started. All outputs are disabled and the FSO is forced to its active low state. An SPI access wakes-up the device and make it enter active mode and Phase 5.

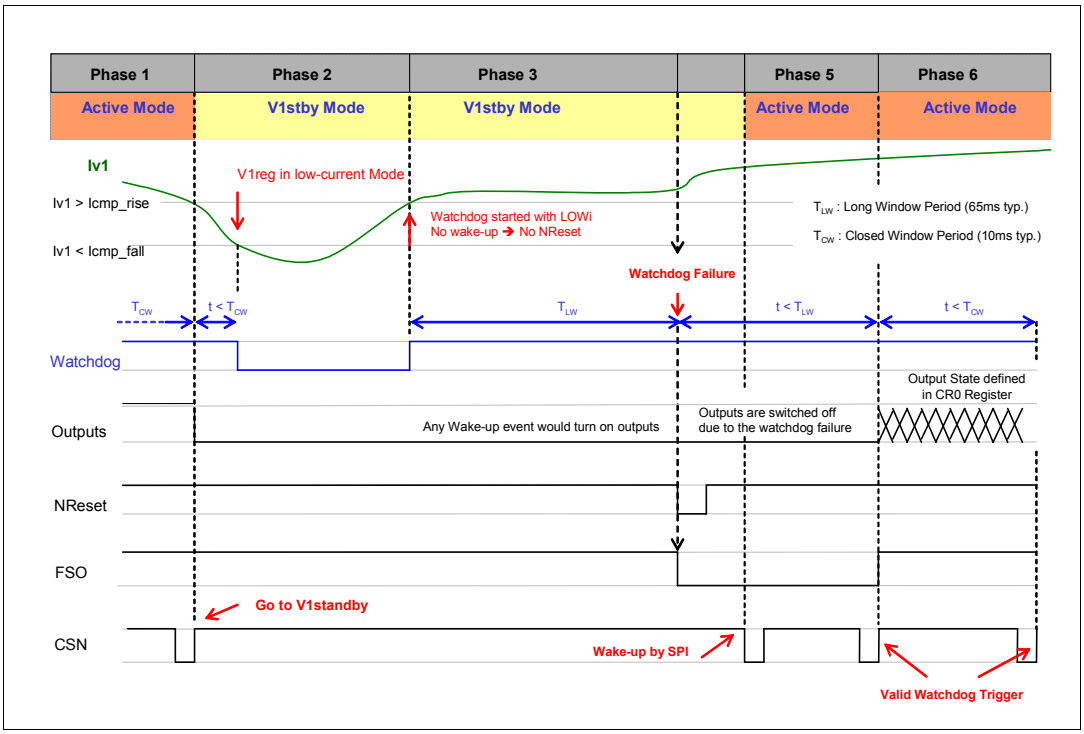
Phase 5

According to the initialization flowchart, the first SPI access following any NReset generation is a read access for Cold start bit evaluation. The FSO remains active.

Phase 6

The next SPI access that successfully triggers the watchdog involves the release of the FSO output so that all the other outputs that will operate according to the previously defined settings. The device is now operating correctly in active mode.

Figure 27. Wakeup from V1_standby after Iv1 > Icmp_rise followed by a watchdog failure



8.3.1 Wakeup from Vbat_standby

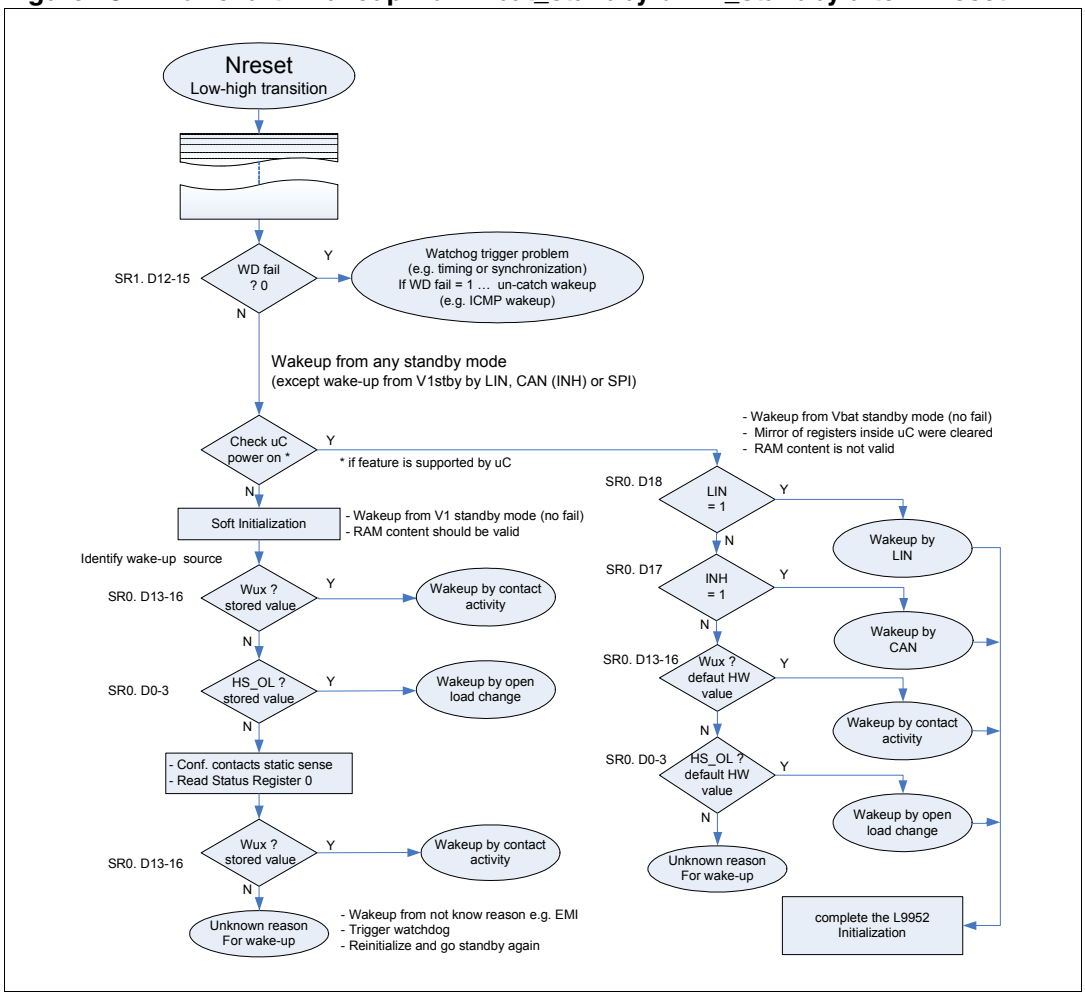
A wakeup from Vbat_standby mode is very similar to the situation following a power ON of the system. The microcontroller memory content is cleared and the microcontroller has to be completely initialized. Only the L9952GXP control registers hold the value which was there before the transition to standby mode. However the microcontroller has no possibility to read these registers. The only one possible solution of this situation is to evaluate the wakeup reason and decide how the L9952GXP should be reconfigured. In the next table is a list of possible wakeup sources from Vbat_standby and the L9952GXP behaviour.

Table 1. Vbat_standby wakeup sources list

Wakeup event from Vbat_standby mode	State transition to Active mode	Watchdog start (LOWi)	Watchdog Trigger	NReset Pulse
Wakeup Input Static Cyclic	 Yes Yes	 Yes Yes	 Write Trig = 1 Write Trig = 1	 yes yes
Open-load OUT1-4	Yes	Yes	Write Trig = 1	yes
LIN	Yes	Yes	Write Trig = 1	yes
INH	Yes	Yes	Write Trig = 1	yes
SPI	No wakeup	No wakeup	No wakeup	No wakeup
Iv1 > Icmp threshold (ICMP=0)	V1 is OFF	V1 is OFF	V1 is OFF	V1 is OFF
Iv1 > Icmp threshold (ICMP=1)	V1 is OFF	V1 is OFF	V1 is OFF	V1 is OFF

The 'power-on/ after wakeup' procedure uses the same flowchart as described in chapter 3.1 'power-on diagnosis'. The relevant part of this flowchart is shown in *Figure 28.*. The Vbat_standby mode can be entered by command of the microcontroller, or this mode can be forced by the L9952GXP after several watchdog fails or repeated over temperature shutdowns. If no fail was detected, it is not possible to decide which type of standby mode the device was waking up from. If the application uses both standby modes (V1_standby and Vbat_standby) the microcontroller has to evaluate if its supply was turned Off or not. For this purpose the microcontroller internal detection feature has to be used, if supported by microcontroller. If the microcontroller doesn't support power on detection, the validity of the microcontroller memory can help to decide if there was a wakeup from V1_standby or Vbat_standby. In case of V1_standby there is no need to initialize all L9952GXP SPI registers, because the internal mirror is still valid. If the microcontroller RAM memory is not valid, the L9952GXP has to be initialized, because the actual state is not known and the evaluation will continue according to the flowchart by the branch valid for wakeup from Vbat_standby. Once it is decided, if the device woke up from Vbat_standby, the wakeup source (CAN, LIN, contact activity or by output open-load state change) has to be identified. All these wakeup sources can wake up the device from Vbat_standby. However the contact activity and open-load state change can be detected only with comparison to the fixed known HW configuration, unless the status of the contacts before entering the standby mode was stored in a non-volatile memory.

Figure 28. Flowchart - wakeup from Vbat_standby or V1_standby after NReset

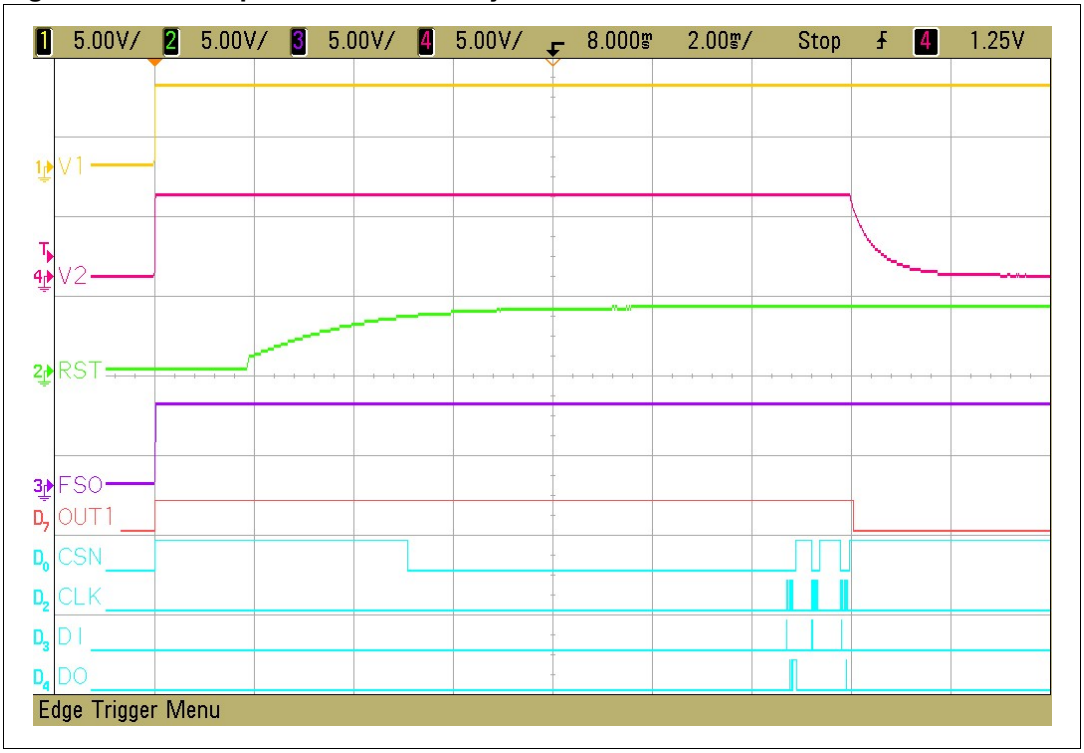


After wakeup from Vbat_standby the outputs will be automatically reinitialized to the states before Vbat_standby mode. An exception is the forced Vbat_standby (entered by the L9952GXP automatically after watchdog failure or thermal shutdown) where the Relx control bits are set to '0'.

After wakeup from Vbat the FSO and NReset are turned to not inactive state (High). *Figure 29.* shows the signal behaviour after wakeup from Vbat_standby. Setup for this screenshot is:

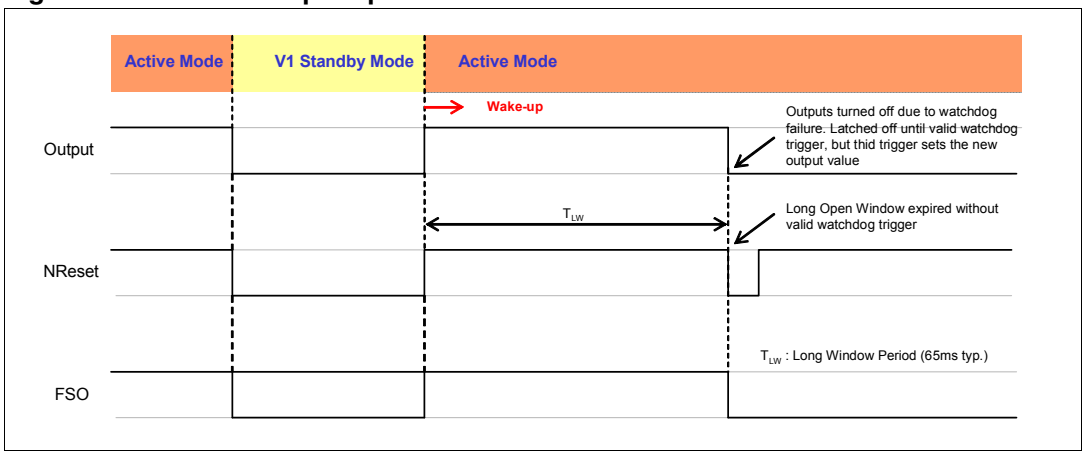
- V2 active in run mode
- Out 1 set to ON before switching to Vbat_standby

Figure 29. Wakeup from Vbat_standby mode



It can be seen that Out1 and V2 is switched on immediately after wakeup. The setup stays active until the watchdog is triggered (in this screenshot the register is written with default values) in the Long Open Window. The default value is V2 off, all outputs Off. If the watchdog is not triggered in this first Long Open Window the same behaviour like after power on is followed. The output behaviour after wakeup from Vbat_standby is shown in *Figure 30.*

Figure 30. Vbat wakeup outputs behaviour



8.4 Wakeup from V1_standby

There are 3 possible cases of behaviour after wakeup form V1_standby. A wakeup by LIN, CAN, SPI & Iv1>Icmp_rise doesn't generate an NReset pulse and the microcontroller has to wakeup simultaneously with the L9952GXP by external signals (LIN Rxd or CAN Rxd) connected to the microcontroller interrupt input. Wakeup of L9952GXP from V1_standby mode by contact activity or open-load state change generates an NReset generation. The microcontroller wakes up by this reset signal and has to evaluate the wakeup source and the previous type of standby mode. The L9952GXP has an extended functionality for the interrupt mode. In this mode, no NReset pulse is generated and the microcontroller can be woken up by a pulse on the interrupt output Dig_out4/INT, which is generated after any possible wakeup source or start of window watchdog (i. e. Iv1 passes Icmp_rise threshold). The next table shows a list of all possible wakeup sources and the L9952GXP behaviour after wakeup from V1_standby mode.

Table 2. V1_standby: wakeup sources list

Wakeup Event from V1_standby mode	State transition to Active mode	Watchdog Start (Long Open Window)	Watchdog Trigger (INT_en = 0)	Watchdog Trigger (INT_en = 1)	NReset Pulse (INT_en = 0)(1)	INT Pulse (INT_en = 1)
WU Input Static Cyclic	 Yes Yes	 Yes Yes	 Write Trig = 1 Write Trig = 1	 Invert Trig Invert Trig	 Yes Yes	 Yes Yes
Open-load OUT1-4	Yes	Yes	Write Trig = 1	Invert Trig	Yes	Yes
LIN	Yes	Yes	Invert Trig	Invert Trig	No	Yes
INH	Yes	Yes	Invert Trig	Invert Trig	No	Yes
SPI	Yes	Yes	Invert Trig	Invert Trig	No	Yes
Iv1 > Icmp (ICMP=0)	No(2)	Yes	Invert Trig	Invert Trig	No	Yes
Iv1 > Icmp (ICMP=1)	No(2)	No	N/A	N/A	No	No

1. If INT_en = 1, no NReset pulse is generated for any wakeup event from V1_standby.
2. V1 regulator is switched to high current mode; outputs remain OFF.

8.4.1 Wakeup with NReset generation

After wakeup from V1_standby with NReset generation, the same initialization procedure like after Vbat wakeup has to be done. Only the microcontroller RAM validity test should be passed. In this case the microcontroller doesn't initialize the L9952GXP, because the actual status of the L9952GXP control registers should be kept in the microcontroller internal mirror. In case of V1 fail, the voltage drop should be detected during the diagnosis procedure already. If the wakeup from V1 without any fail is confirmed, the microcontroller should finish the necessary configuration and start the detection of the wakeup source. The possible wakeup sources which can be detected are wakeup by contact activity or wakeup by Out 1..4 open-load state change. The WU input state should be evaluated first. The value received at the first access to SR0 should be compared with the value stored before going to

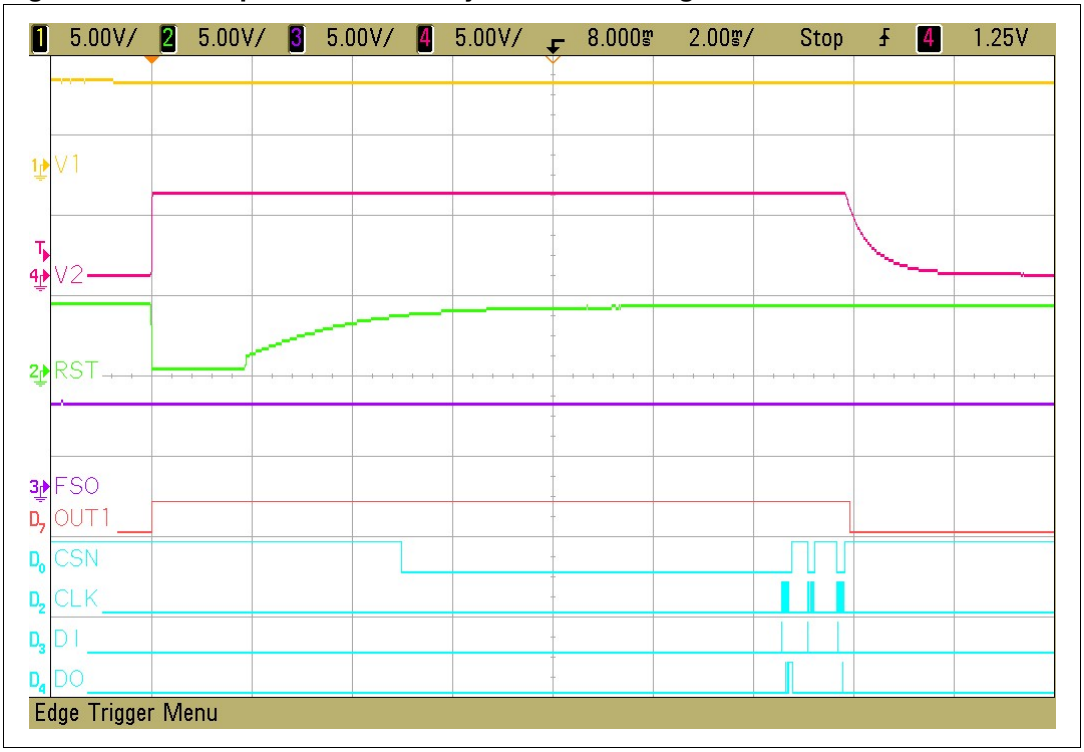
standby mode. If there is some difference the WU input with the changed state is identified as the wakeup source. If the WU inputs are confirmed to be unchanged, the open-load state at Out1-4 should be evaluated. Again the first access to SR0 should be compared with stored value. If no wakeup source was detected during this diagnosis, it is recommended to configure the WU inputs to static sense and repeat the evaluation. If No wakeup source was recognized, the reason for the wakeup remains unknown. EMI could be a possible reason for the wakeup. Further proceeding is dependent on system requirements. It is recommended to re-initialize the L9952GXP and go to standby mode again.

Figure 31. shows the signal behaviour after a typical wakeup from V1_standby by external contact or change of HS open-load state.

The setup for this screenshot is:

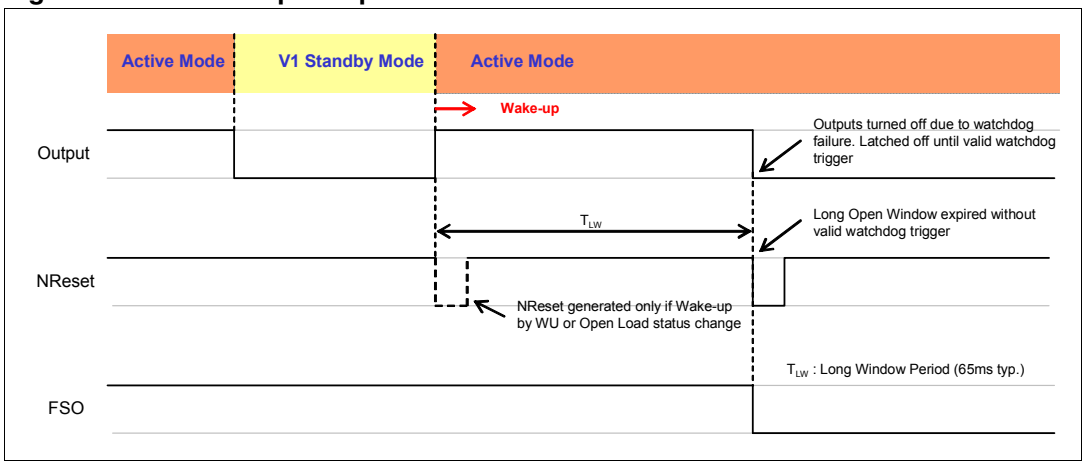
- V2 active in run mode
- Out 1 set to ON before switch to V1_standby

Figure 31. Wakeup from V1_standby mode / NReset generated



The behaviour of NReset and FSO signals after wakeup from V1_standby is different compared to the wakeup from Vbat_standby. In Vbat_standby mode, the NReset and FSO signals are pulled to GND (these output stages are powered from the V1 regulator). In V1_standby mode these signals stay in not active state (High). After wakeup, NReset is pulled low for 2ms. FSO remains high after wakeup until a WD early write failure occurs or the WD LOWi expires without watchdog trigger. The outputs behaviour after wakeup from V1_standby mode is shown in *Figure 32.*.

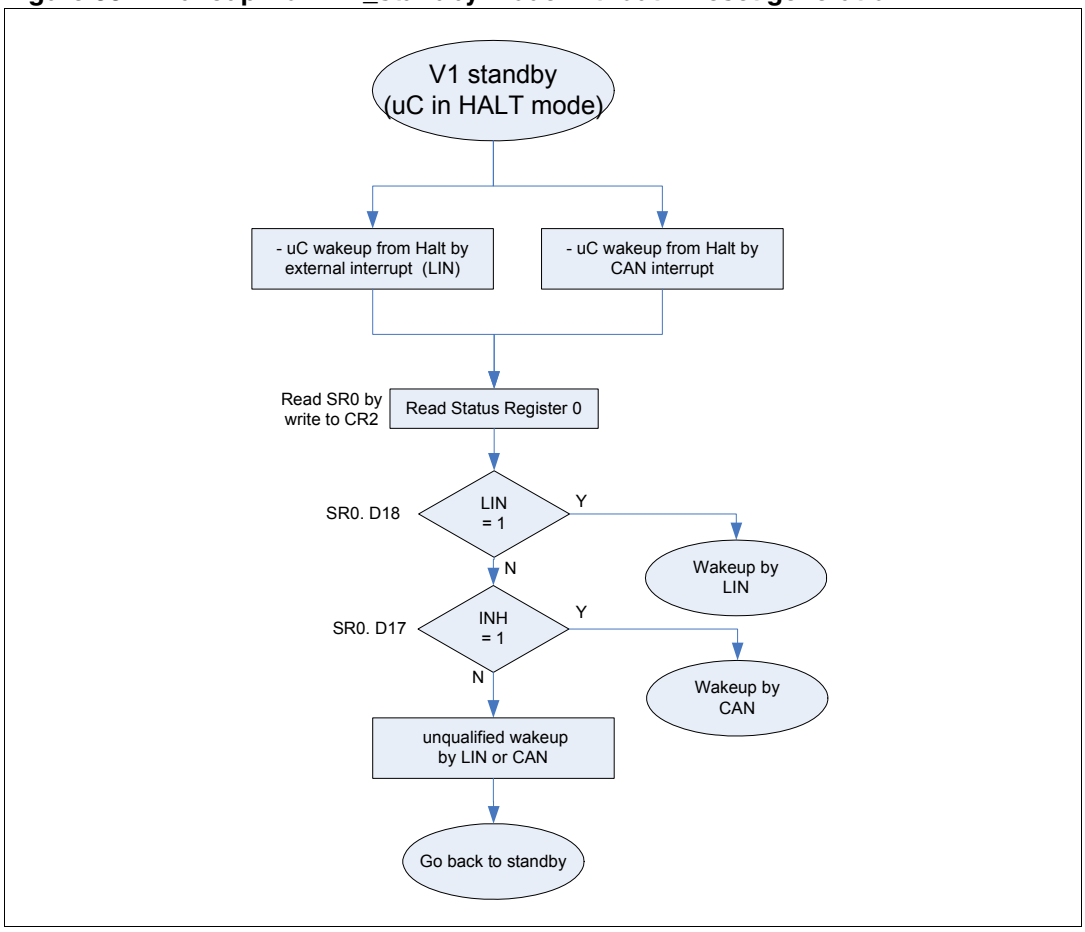
Figure 32. V1 wakeup - outputs and FSO behaviour



8.4.2 Wakeup without NReset generation

A wakeup by LIN, CAN, Iv1 > Icmp_rise or SPI access does not generate an NReset pulse. If the interrupt mode is not active the microcontroller can wakeup by the LIN RxD or CAN RxD signal connected to the microcontroller CAN. The flow chart for this situation is in *Figure 33.*.

Figure 33. Wakeup from V1_standby mode without NReset generation



After exit from halt mode the microcontroller has to evaluate the source causing the wakeup. It can be an external interrupt, wakeup by CAN activity or some other source with dependence on HW configuration of the system. SR0 contains the LIN and INH status bits which indicates that the wakeup occurred due to an activity on LIN or via INH.

In the case of a LIN wakeup, the L9952GXP integrated LIN transceiver wakes up the IC and the LIN state is transferred to the LIN RxD output which subsequently wakes up the microcontroller. As in V1_standby mode the LIN RxD output is floating, so if a High level in standby mode is required, an external pull-up resistor (10 kΩ) has to be used.

Figure 34. shows the signals for a LIN wakeup by transition from dominant state to recessive and *Figure 35.* shows a wakeup by transition from recessive to dominant state. Both situations are shown for a configuration without a pull up resistor at RxD (right) and with a pull-up resistor of 10 kΩ on the RxD line (left).

The setup for the next screenshots are:

- Chanel 1 (yellow) LIN RxD
- Chanel 4 (red)LIN
- Chanel 2 (green)V2 (active in RUN mode)

Figure 34. Wakeup from V1_standby by LIN (dominant to recessive) with / without pull-up

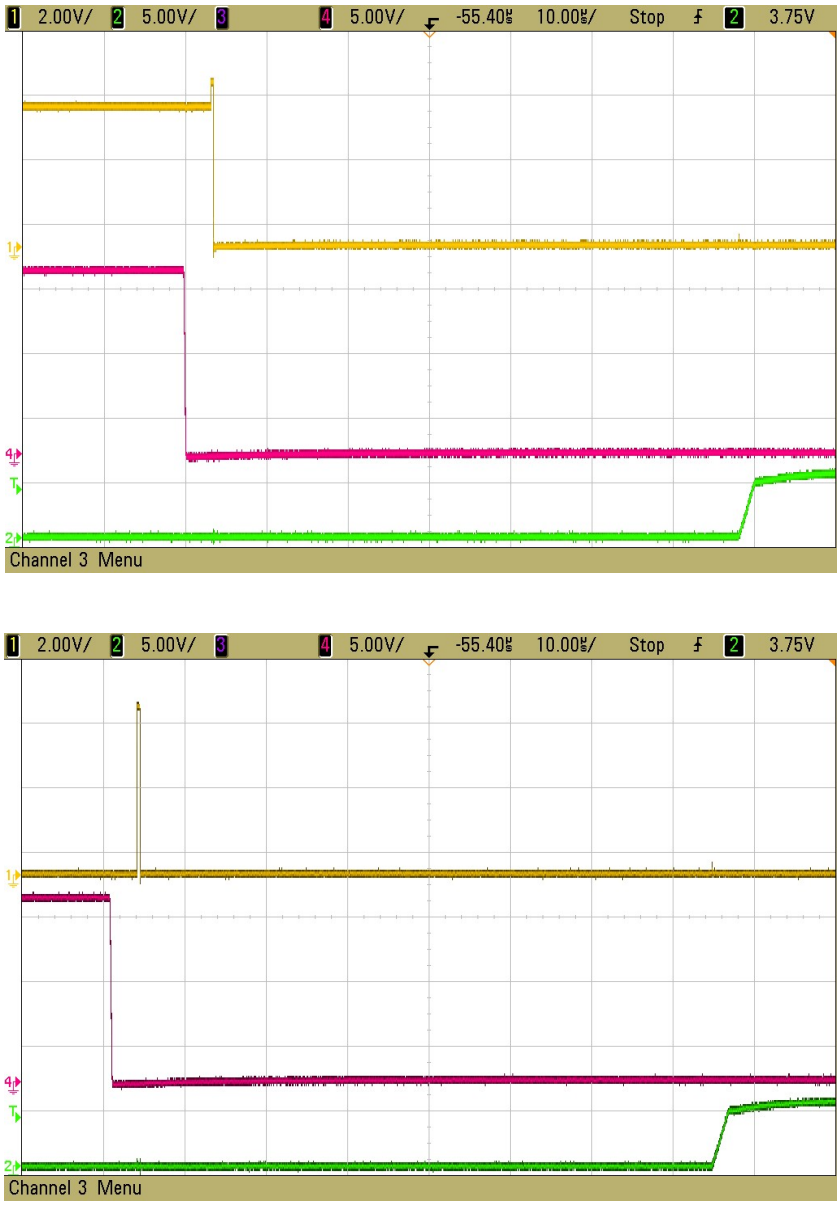
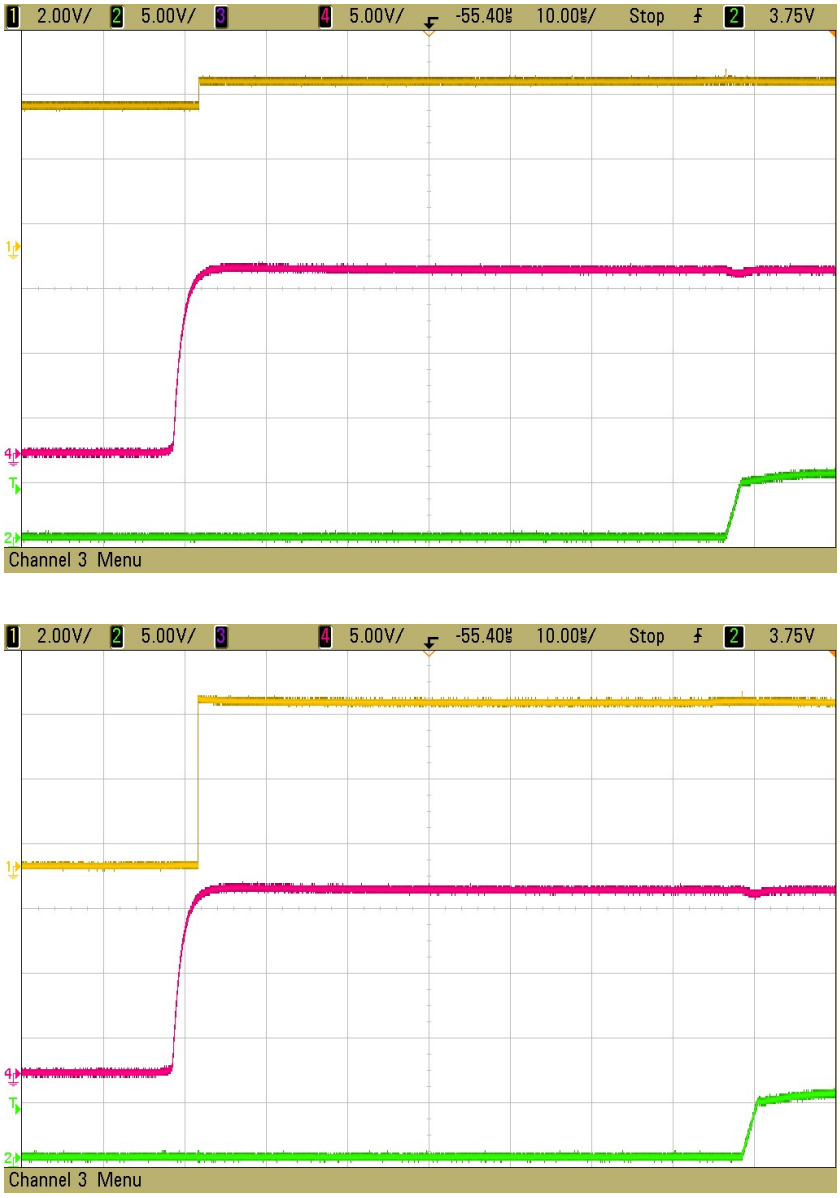


Figure 35. Wakeup from V1_standby by LIN (recessive to dominant) with/without pull up



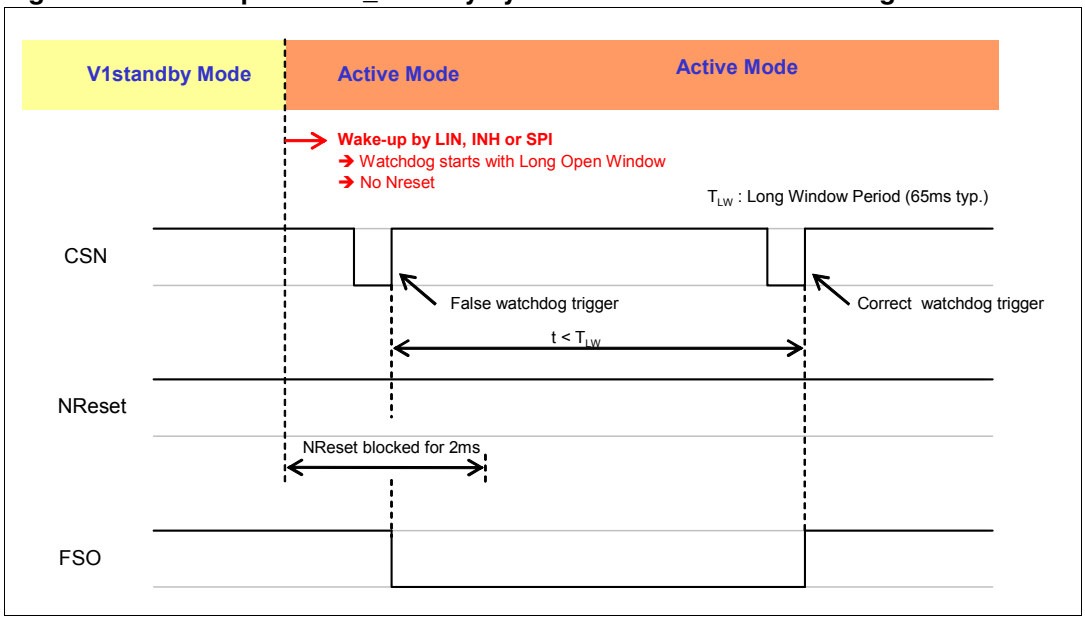
If the L9952GXP should wakeup by CAN, it can be done by different ways. The L9952GXP device offers an Inhibit input which works like a wakeup input. Typically, the INH signal provided by the CAN Transceiver pulls this pin to Vs level. The L9952GXP wakes up if the current exceeds the threshold of 200µA. The CAN activity is stored as the wakeup source in SR0.

The ways how to wakeup by CAN are follows:

- If the inhibit pin is connected to the CAN transceiver INH output and the L9952GXP wakes up by activity at this pin, the microcontroller will wake up by CAN RxD, which is connected between uC and CAN transceiver. If the microcontroller doesn't catch this wakeup, the watchdog LOWi expires and the microcontroller is reset.
- The next way is the same like the previous, but Interrupt mode of L9952GXP is activated. In this case the uC will wakeup by a high level at the interrupt input. This external interrupt input has to be connected to the L9952GXP Dig_out4/INT output which is used in interrupt mode as an interrupt output.
- In case that the INH input of the L9952GXP is not used, the microcontroller wakes up by activity on the CAN RxD line but the L9952GXP does not recognize this event. The L9952GXP watchdog starts as soon as the microcontroller increases the current consumption (Iv1 > Icmp).
  If the ICMP bit is set (Iv1 current comparator is disabled) the microcontroller wakes up, but the L9952GXP stays in V1_standby mode and the watchdog is not activated. Therefore, this configuration is not allowed.

After a wakeup of the L9952GXP by LIN, CAN (INH) or SPI and after a watchdog start due to Iv1 > Icmp_rise, no NReset pulse is generated and the NReset output is blocked for 2ms. As a consequence, an additional wakeup event by WU input or change of open-load state does not cause an NReset generation during these 2ms. Also, a watchdog failure (LOWi stopped with first watchdog trigger and immediate Early Write failure) does not cause an NReset generation during this time. However, the FSO signal is activated. This situation is shown in *Figure 36.*.

Figure 36. Wakeup from V1_standby by CAN or LIN – NReset blockage



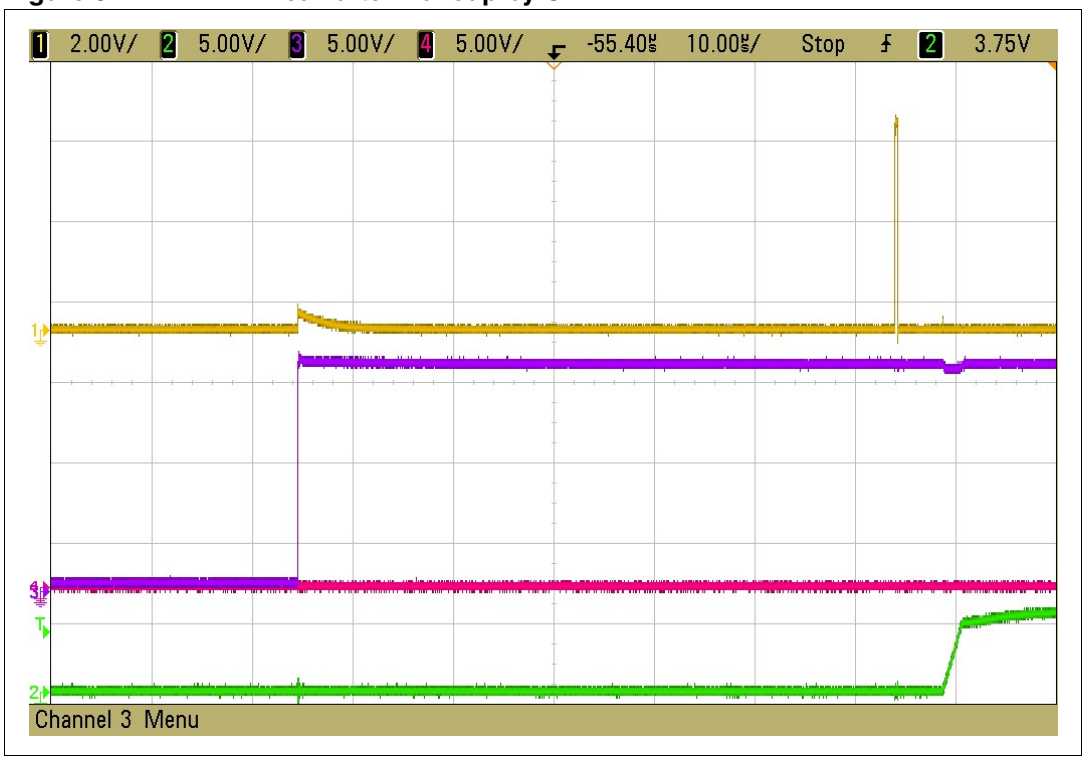
Because of L9952GXP internal logic hazard, in some case of CAN wakeup the microcontroller will be waked up by LIN_ RxD, if this pin is used as a wakeup source and no pull up at this input is connected. After Inhibit pin activity the L9952GXP wakeup and the LIN RxD output is activated. When LIN is in standby mode in recessive state (Hi) the rising edge on RxD is generated. When the LIN is in standby mode in dominant state (Lo) there is generated a peak on LIN RxD after wakeup by CAN. In dependence of microcontroller

configuration the peak at LIN RXD can be caught before the CAN wakeup condition. By reading of the SR the exact wakeup condition should be detected. Example of this behaviour is at screenshot in *Figure 37.*.

The setup for this screenshot is:

- Chanel 1 (yellow) LIN RxD
- Chanel 3 (blue)Inhibit
- Chanel 4 (red)LIN
- Chanel 2 (green)V2 (active in RUN mode)

Figure 37. LIN RxD Peak after wakeup by CAN



9 Digital outputs

In both active and V1_standby modes, the Outputs Dig_out3 and Dig_out4/INT offer the possibility to transmit real time signals from the operating side to the processing side of the application without waiting for a periodical SPI access. Three different configurations are possible:

- Direct Looping of WU inputs when status changes.
- Direct Looping of High-side open-loads when status changes.
- Interrupt generation when waking-up from V1_standby mode.

A significant advantage of direct looping is the possibility to transmit signals coming from the WU inputs Pins - at Vs voltage level to the Digital output Pins - at TTL voltage level e.g. 5V.

The direct looping of open-load status from High-Side Outputs is specifically implemented to connect Hall sensors outputs requiring high real time processing speed. For this purpose the open-load threshold current is configurable on HS Drivers 1 to 4 between 2mA and 8mA (CR2 -bits 0 to 3).

The following Signals can be looped:

- WU3 and WU4 status (CR1-12 to 14) looping to Dig_out3 and Dig_out4.
- HS Out1 and Out2 open-load status (CR1-12 to 14) looping to Dig_out3 and Dig_out4.

The validity of the looped information is dependent on the operating modes (Static, Timer 1 or 2) and on the WU or HS open-load configurations. All factors influencing information at the Digital Outputs will be summarized within this chapter.

Additionally the Dig_out4/INT output can be configured (CR1 bit 20) to generate an interrupt signal to the microcontroller (2ms active high pulse) in case of waking-up from V1_standby mode through WU inputs, LIN, INH, SPI, HS open-load and $I_{V1} > I_{CMP\_ris}$. When INT_enable is set to 1 (CR1 bit 20) the looping Option on Dig_out4 are disabled and the **NRESET generation is disabled**. This specifically address applications whom microcontroller must preserve its memory content and have a fast wakeup and fast recovery after interrupt generation.

9.1 Looping WU inputs in V1_standby mode

The looping of WU inputs or High-side open-load signals is **only possible in active or V1_standby modes**. The following chapter specifically covers the behaviour of the Digital Output signals Dig_out3 and Dig_out4 in V1_standby mode.

Note: By default, in Vbat_standby mode, the digital outputs DO are pulled-low. Anyhow depending on the configuration, the digital outputs can still reflect the High-side open-load status. But considering that in Vbat_standby mode the High-side outputs are switched-off and that the digital output push-pull stages are no more supplied, the internal clamping diodes impose a low level on the digital output stages and no floating signals are issued.

9.1.1 Static filter on WU3 rising-edge

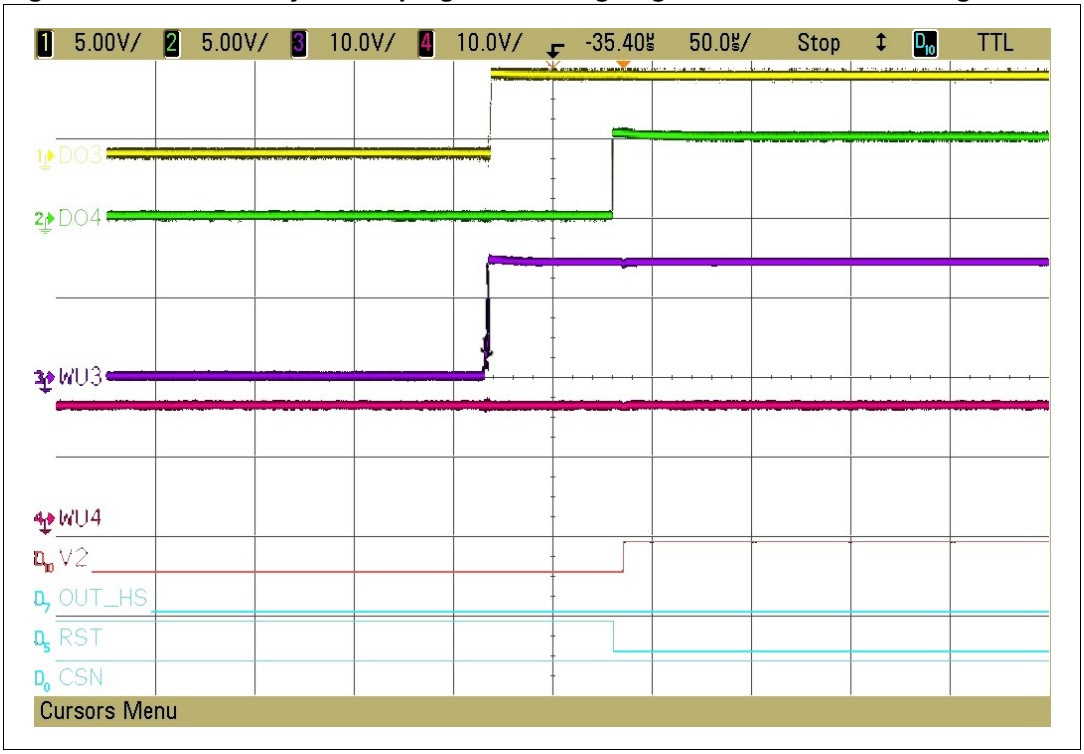
In V1_standby mode, if the static filter is selected on WU inputs 3 and 4, the Digital outputs are set to low level and do not reflect the WU inputs status.

Two consecutive and independent events have to be differentiated:

1. As soon as the WU input status changes (a wakeup request voltage is detected - e.g. $V_{wu} > 1V$ or $V_{wu} < V_{s-2V}$ - this change is immediately transferred to the corresponding digital output.
2. If the input voltage passes the wakeup threshold voltage – e.g. 0,55Vs for a positive-edge – for a least 64us (default static filtering period) the device wakes up and enters active mode. The status of the second WU input is then transferred to the corresponding digital output. For a detailed description of Static WU filtering behaviour please refer to *Figure 16.: Static wakeup by active-high contacts*.

Figure 38. illustrates such Static Filtering functionality. A WU3 status change is immediately transmitted on Dig_out3 output, then after 64 µs (default static filtering period) the L9952GXP wakes up and WU4 status is looped to Dig_out4 output. The internal NReset is pulled low and voltage regulator V2 is switched- on according to its previously configured setting.

Figure 38. V1_standby DO looping: WU3 rising-edge event in static filtering



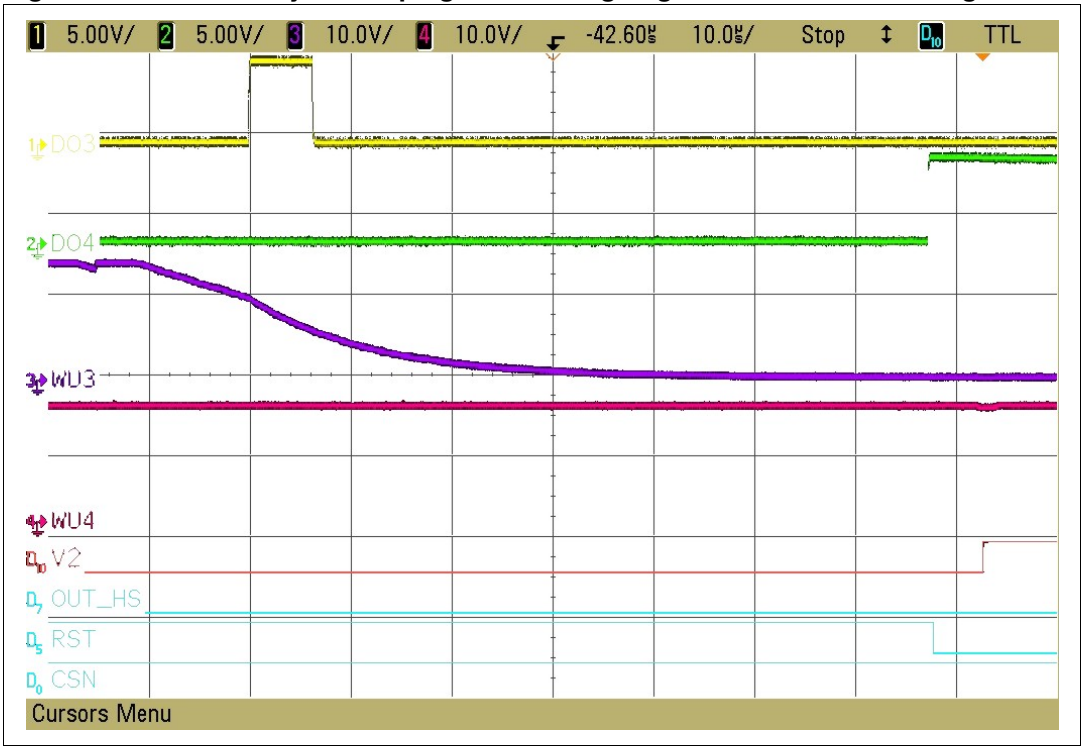
9.1.2 Static filter on WU3 falling-edge

In *Figure 39.*, in V1_standby mode, a slow falling edge on WU3 input wakes up the device:

on this example we can see even better the two consecutive and independent events:

1. The Dig_out3 looping is activated when WU input voltage reaches the WU request threshold high V_{WUthh} (at V_{S-2V}). At that time, Dig_Out3 is switched to High. and then turned to Low when the WU input voltage goes below the wakeup request threshold low V_{WUthl} (at 1V).
2. In case the input voltage passes the wakeup threshold voltage – e.g. 0,45Vs for a negative-edge – for a least 64µs (default static filtering period) the device wakes up and enters active mode. At that time the WU4 status is looped to Dig_out4 output and the internal NReset is pulled low. The voltage regulator V2 is then switched-on according to its previously configured setting. For a detailed description of Static WU filtering behaviour please refer to *Figure 17.: Static wakeup by active-low contacts* .

Figure 39. V1_standby DO looping: WU3 falling-edge event in static filtering



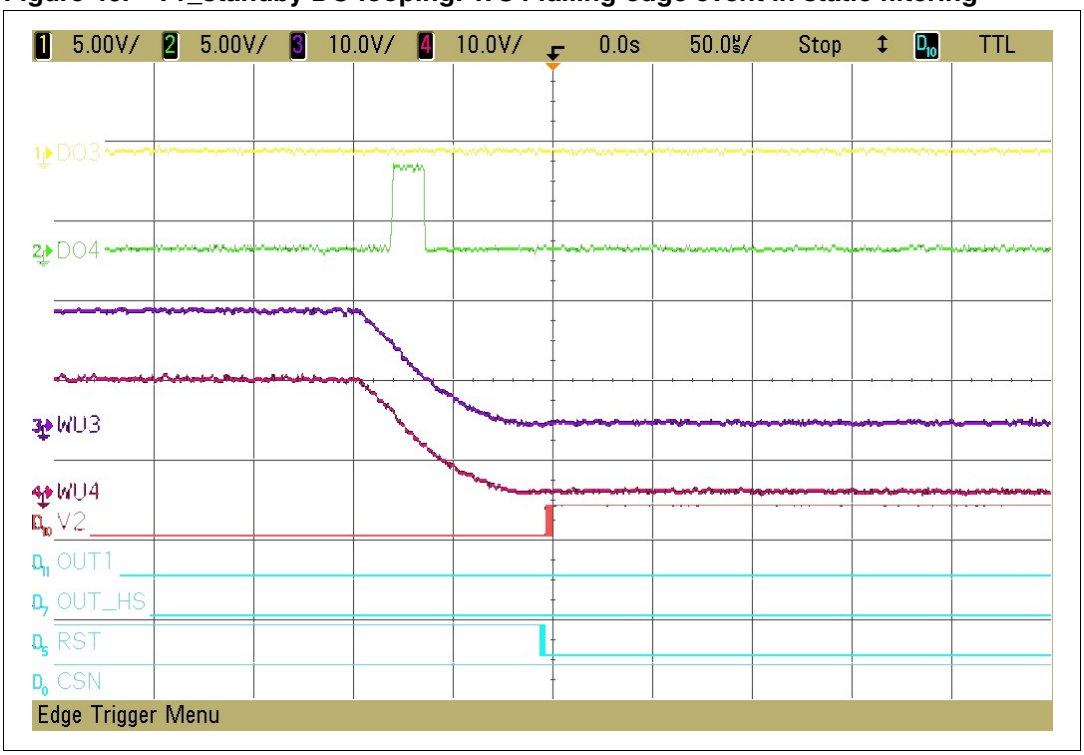
Note: In the case of a very short falling-edge on WU3, the looped signal to Dig_out3 could be partially or completely filtered by the L9952GXP internal logic. Anyhow, if WU3 input voltage status changed for at least 64us, the L9952GXP will wake up and the WU source will be stored within SR0 - bit 15 (for WU3). In this case, the microcontroller will retrieve the WU source through SPI access. That means that the falling-edge WU-event configuration is not the fastest one. We recommend monitoring of rising-edge WU events if your application needs fast waking-up from V1_standby mode.

9.1.3 Static filter on WU4 falling-edge

In V1_standby mode and in case the WU3 input is disabled (CR1 bit 2) as a wakeup source, a transition on this input does not wake up the device and the WU3 input status is not looped.

This scenario is illustrated in *Figure 40.* where the WU3 input is disabled. In this example the wakeup is caused by the changing level on WU4. This is illustrated by the Dig_out4 signal behaviour.

Figure 40. V1_standby DO looping: WU4 falling-edge event in static filtering

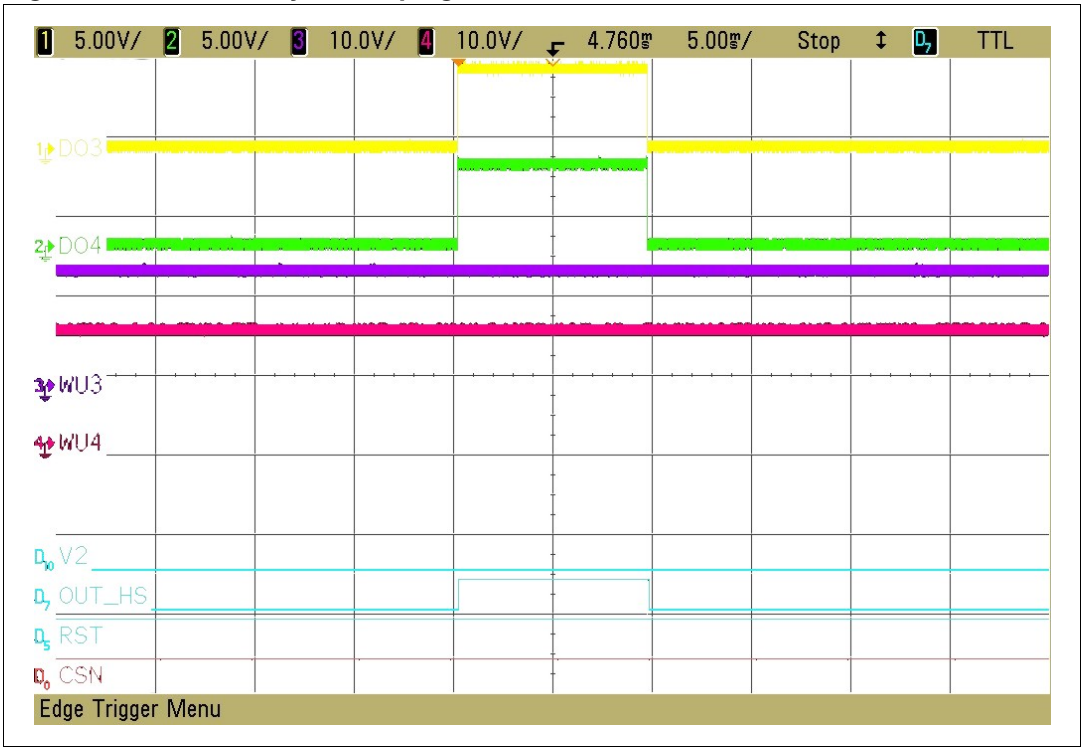


9.1.4 Timer 1 filter on WU3 and WU4

In V1_standby mode, we have a different behaviour if the WU input filter is configured to any timer mode. In this case, the WU input level is looped to the Digital Output only during the Timer On-time in accordance with the specified input filter configuration (CR2 bits 10-17). During timer Off-time, The WU input level is not reflected anymore and the Dig_Out is permanently polled-low.

Figure 41. illustrates this behaviour with the WU3 and WU4 filters configured to Timer 1 mode. The WU input are permanently connected to Vs. The output Out_HS is set also to timer 1 mode in order to reflect the timer signal. This figure shows the looping of the WU3 and WU4 inputs to Dig_Out3 and Dig_Out4 outputs but only during On-time of the Timer.

Figure 41. V1_standby DO looping: WU3 and WU4 filters in Timer 1 mode



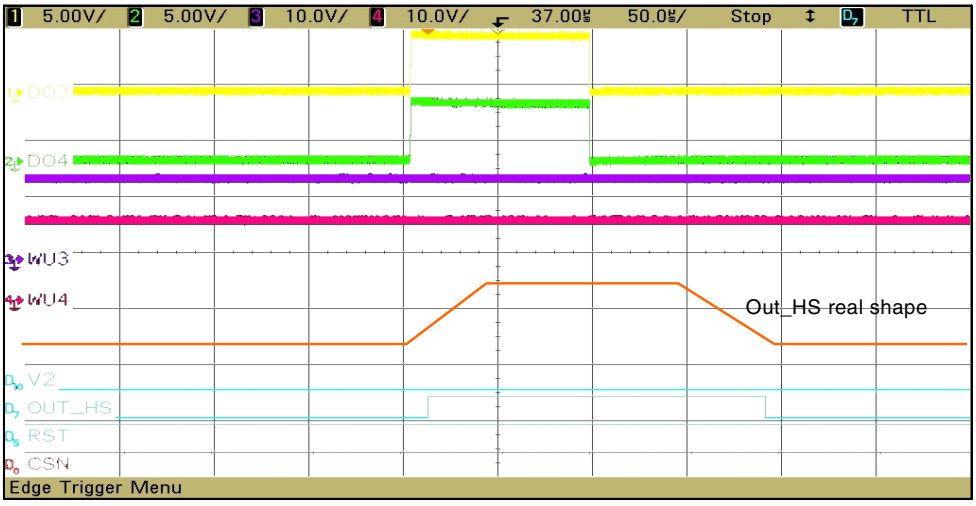
9.1.5 Timer 2 filter on WU3 and WU4

The following example illustrates a fast looping of WU3 and WU4 input signals to the Digital outputs Dig_Out3 and Dig_Out4 in V1_standby mode. WU3 and WU4 are permanently supplied by external Vs and their input filters have been configured in Timer 2 mode e.g. 50ms period and 0.1ms On-Time. These are the fastest configurable timer settings.

We can that the Dig_Out3 and Dig_out4 periodically reflect the status of WU3 and WU4 inputs with a fast reaction time. The Out_Hs output port has also been configured in timer 2 mode and we see that due to the external load, the Out_Hs output signal is delayed. This is why in cyclic sense mode and when the Out_Hs output is used for external contacts supplying, a minimum stabilization time has to be respected before starting the contact sense in any filter mode. For details on this configuration, please refer to the chapter cyclic contact sense.

Depending on the targeted application the digital output looping of static supplied WU inputs is the fastest procedure to interface with the microcontroller.

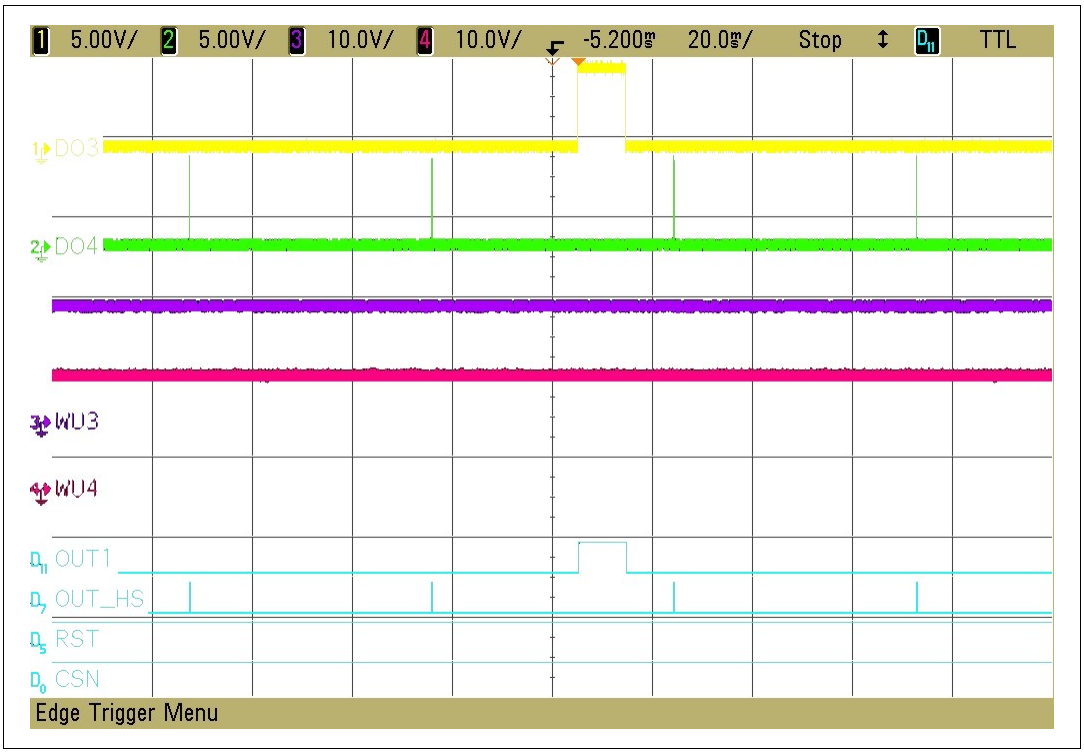
Figure 42. V1_standby DO looping: WU3 and WU4 filters in timer 2 mode



9.1.6 Timer 1 filter on WU3 and timer 2 filter on WU4

The following figure shows a screenshot where the WU3 filter is set to Timer 1 mode and WU4 filter to Timer 2 mode. This illustrates the possibility to configure the digital outputs with different WU filter settings in case of different monitoring requirements for static supplied contacts.

Figure 43. V1_standby DO looping: WU3 filter in timer 1 and WU4 filter in timer 2 mode



Note: If the WU3 and WU4 are looped to DigOut3 and DigOut4 and at least one output is switched to timer 1 mode and one to timer 2 the WU filter can be set to any combinations and wake up functionality works.

But if

the outputs are switched off or to same timer mode, the combination of different WU filters is not possible. The device is reset after turn to V1_standby mode. This happen also when WU inputs are not powered by Outputs, only when WU input filters are set differently and outputs are not set to both timer modes.

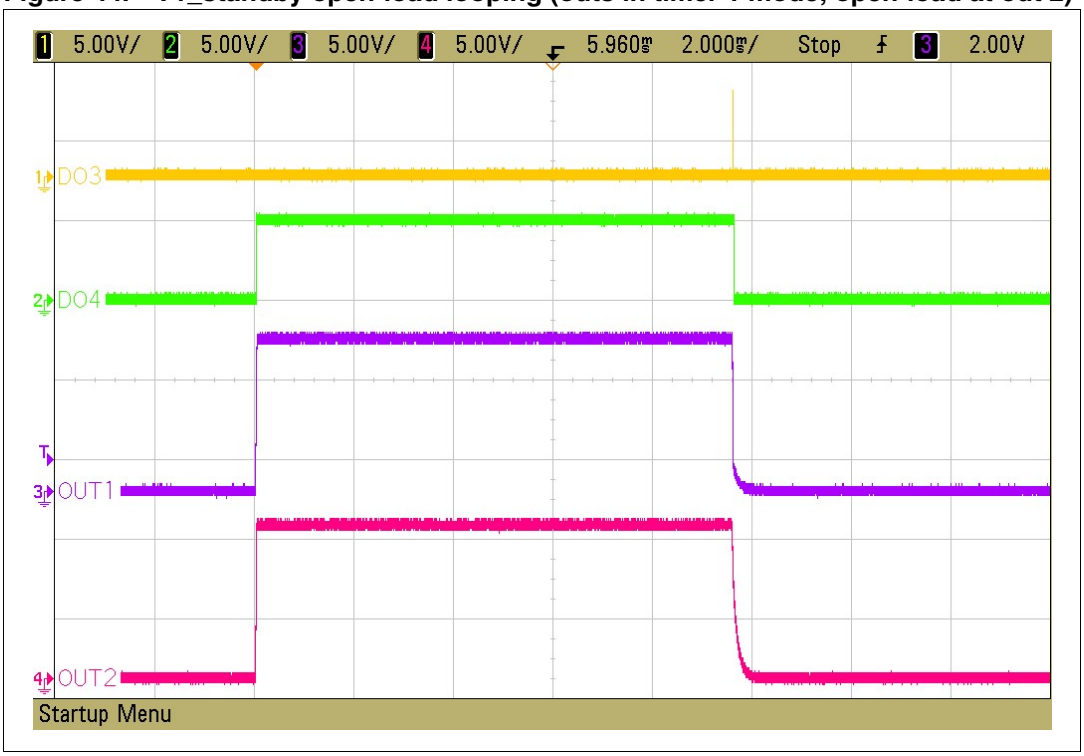
9.2 Looping HS open-load status

9.2.1 Timer 1 filter on HS_out open-load

If Dig_Out3 or Dig_Out4 digital outputs are configured in HS_Out1 or HS_Out2 open-load loop, if the High-side is turned-on and if an open-load event occurs then a High level signal issued on the corresponding digital output. If no open-load event is detected, the corresponding digital output signal will remain low. Additionally in V1_standby mode, if the Digital outputs are configured in timer mode, the HS outputs are active only during timer-on time. For this reason the open-load information is looped only during timer-on time.

Figure 44. illustrates an open-load status detected on HS_Out2 and looped to Dig_Out4. On this screenshot the HS_Out1 and HS_Out2 were both configured to timer 1 mode. Dig_Out4 reflects the open-load condition of HS_Out2. Dig_Out3 remains low, reflecting a normal behaviour of the output stage HS_Out1 but a short peak is issued at the end of the timer-on Time. This peak has to be filtered by SW.

Figure 44. V1_standby open-load looping (outs in timer 1 mode, open-load at out 2)

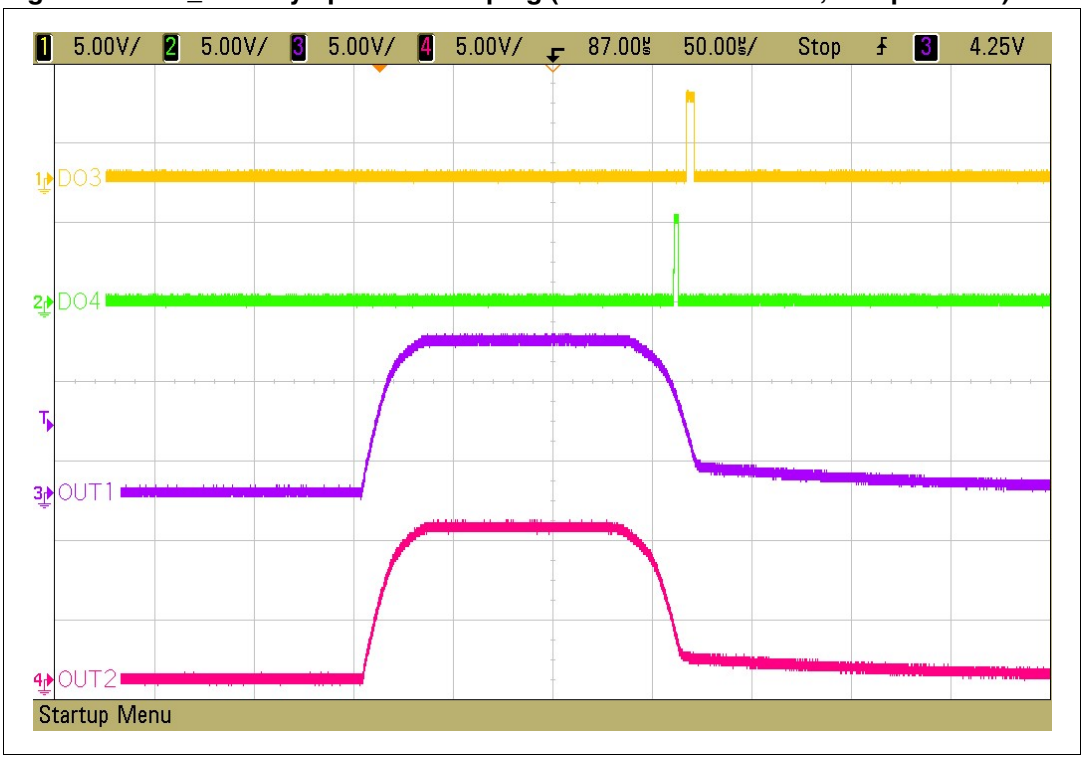


9.2.2 Timer 2 filter on HS_out open-load

Figure 45. illustrates the behaviour of the digital outputs in timer 2 mode. On this screenshot, we see that no open-load event is looped because there is no open-load event on HS_Out1 or HS_out2, but we see that both digital outputs issue a small peak that has to be filtered by the microcontroller software routine.

Depending on the targeted application the digital output looping of any HS open-load event is the fastest way to interface with the microcontroller from the output stages.

Figure 45. V1_standby open-load looping (outs in timer 2 mode, no open-load)



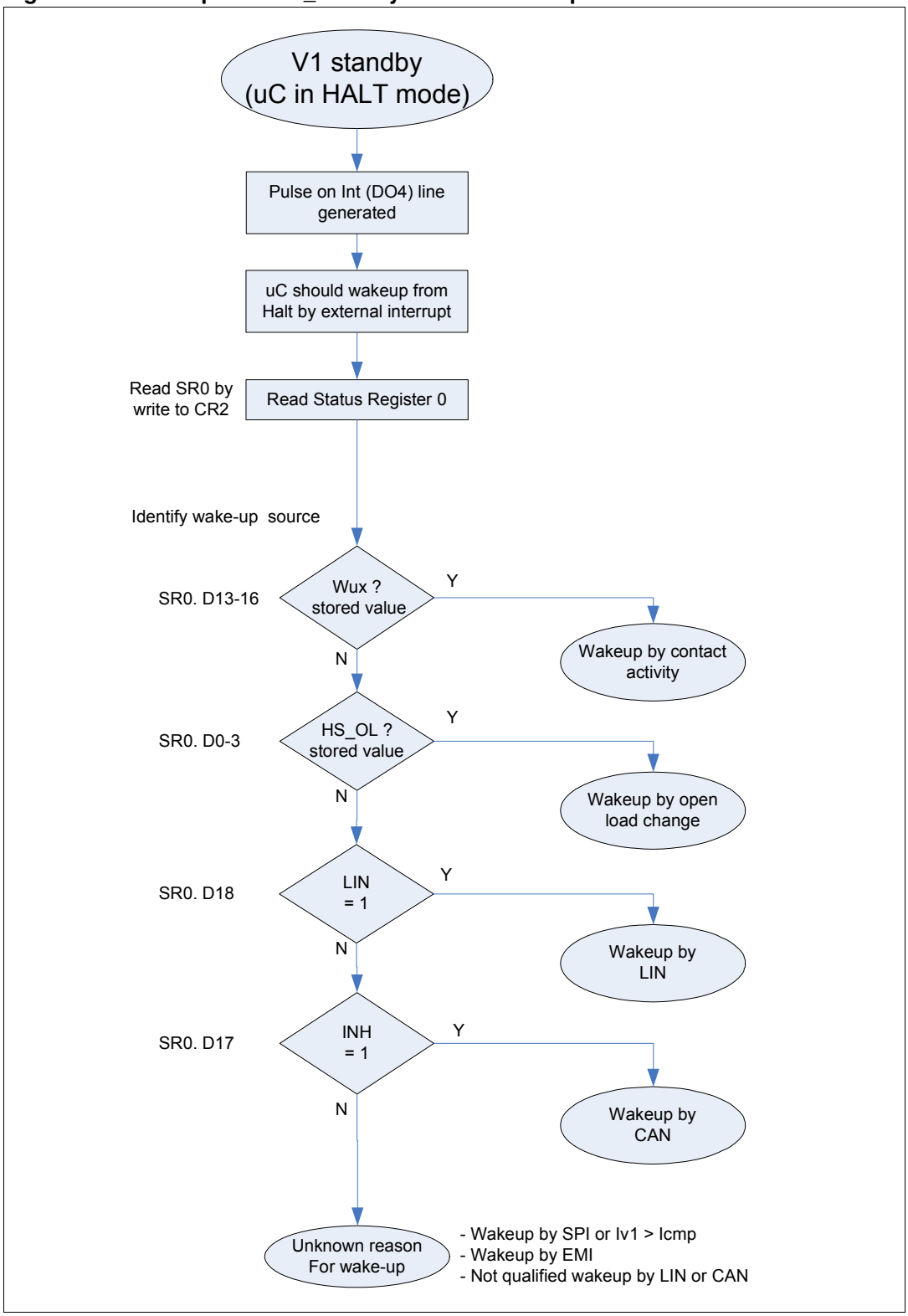
9.3 Interrupt mode

The L9952GXP offers a configurable Interrupt mode. By setting bit 20 in CR1 the Interrupt mode is activated. In this mode, after any wakeup from V1_standby mode the NReset signal is blocked and a positive Interrupt Pulse (2ms) is generated on Dig_Out4. The looping of open-load or WU input status is disabled on Dig Out.4.

After wakeup of this interrupt signal, the microcontroller memory content stays valid and the microcontroller continues with the program execution after exit from HALT mode. The reason of wakeup should be evaluated according to the flow chart in *Figure 46.*. The content of SR0 should be read by writing to CR2 or CR0. In this mode, writing to both Control Registers is possible in order to read SR0, because, all SPI registers in the microcontroller mirror should still be valid. The order of wakeup source evaluation is in this case application specific and there are no limitations regarding the order.

The WU input status should be compared with values stored in the microcontroller before transition to V1_standby mode. Also the change of open-load state should be evaluated and compared with the stored values. If no wakeup event is detected, the LIN or INH bit can hold the wakeup source information. If no wakeup source is detected, it is possible that the interrupt is caused by Icmp_rise (Iv1 >Icmp_rise) or SPI.

Figure 46. Wakeup from V1_standby mode in interrupt mode



If the microcontroller wakes up (e. g. by auto-wakeup timer) and sends any SPI message to the L9952GXP, the device wakes up from V1_standby and generates an interrupt signal on Dig_Out4.

This is possible only in case of current consumption of microcontroller less than Icmp threshold or when the V1 current comparator was disabled.

In other cases the Icmp wakeup occurs before the SPI wakeup. The Icmp wakeup occurs in case of microcontroller current consumption increase over the Icmp_rise current threshold.

The Icmp wakeup, and also SPI wakeup, is not indicated by the L9952GXP Status registers, however, since the microcontroller itself is the source of the wakeup such indication is not required.

In interrupt mode, if Iv1 > Icmp the L9952GXP generates an interrupt pulse (2ms). If the Iv1 current decreases under threshold in this 2ms time, the INT pulse is stopped and the device stays in V1_standby mode. When Iv1 increases over threshold again the same procedure is repeated. As soon as the current at V1 stays above the threshold for more than 2 ms, the watchdog is started at the beginning of the 2ms INT impulse with a Long Open Window. If Iv1 decreases below the threshold during LOWi, the device stays in V1_standby mode and the procedure can be repeated after next Iv1 increase. *Figure 47.* illustrates the behaviour.

Since the Icmp wakeup is not a real wakeup, the L9952GXP stays in standby mode, only the WD is started, the device is turned to Active mode by SPI communication. As mentioned before, the SPI wakeup also generates an INT pulse. However, in this case no INT is generated since the WD is already running. *Figure 48.* shows the behaviour.

Figure 47. V1_standby in INT mode - wakeup by V1 current monitoring

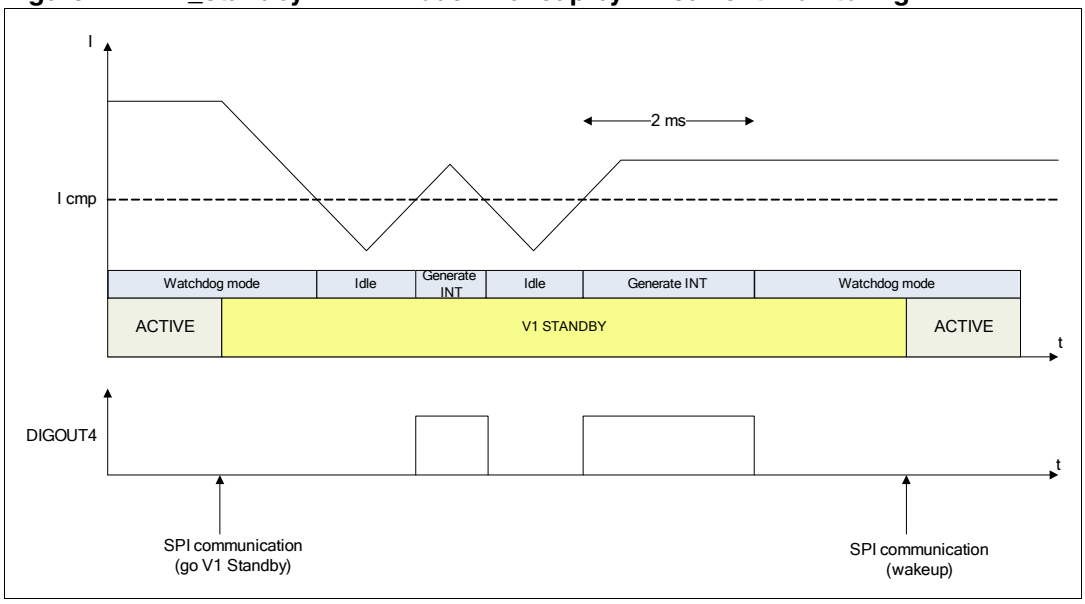


Figure 48. V1_standby in INT mode - wakeup by V1 current monitoring

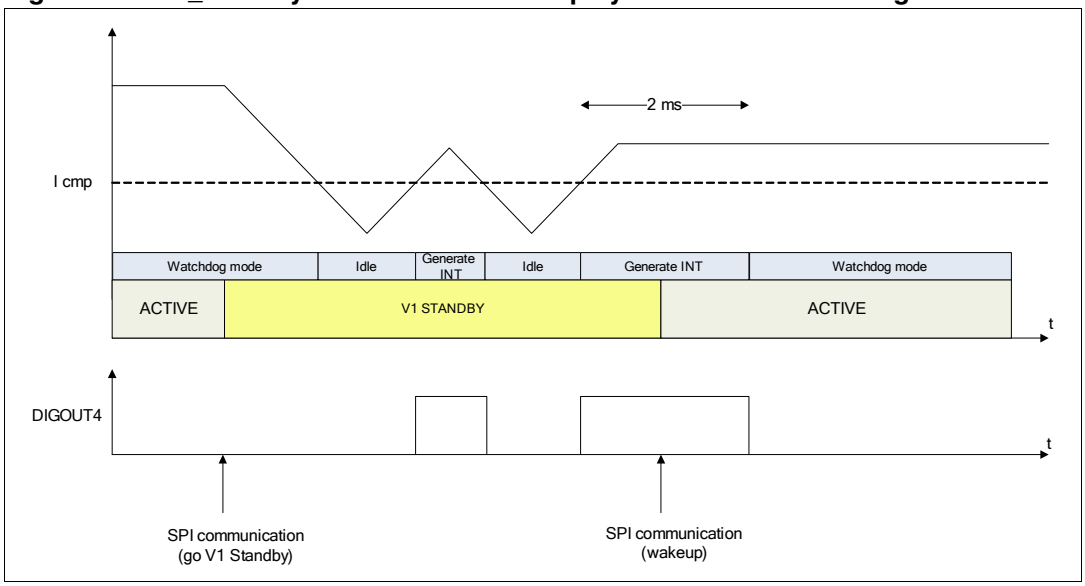


Figure 49. shows the typical behaviour after wakeup from V1_standby in interrupt mode. In this case a 2ms pulse is generated at Dig_Out4. NReset is blocked for all wakeup sources.

The setup for this screenshot is:

- Out1 turned On before transition to V1_standby
- V2 = On in Active mode
- Interrupt mode active
- Wakeup by WUs / OLs / INH / LIN / SPI

Figure 49. Wakeup form V1_standby in interrupt mode

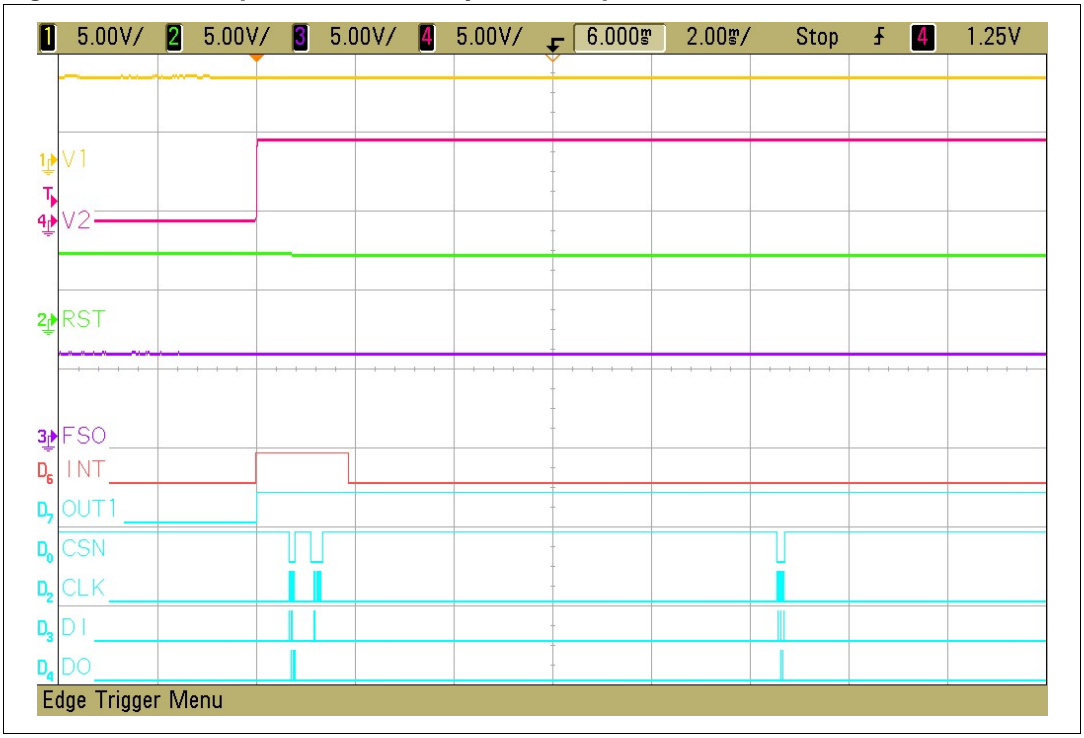
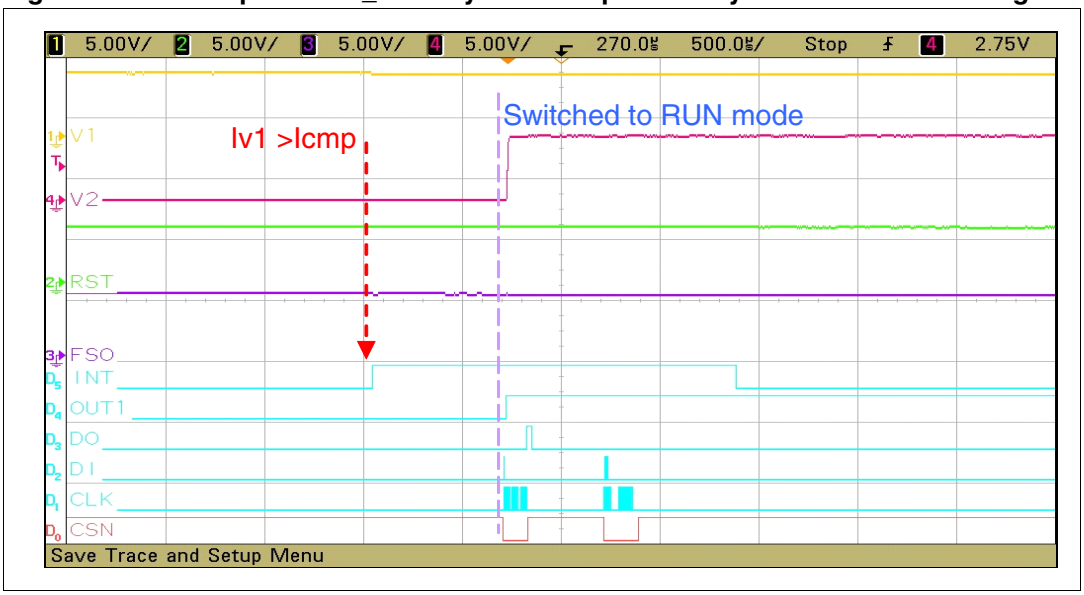


Figure 50. shows the behaviour if Iv1 reaches the Icmp_rise threshold in V1_standby mode when Interrupt mode is enabled. It can be seen that the device turns to Active mode after the first SPI communication. (CSN low and first rising edge on CLK)

The setup for this screenshot is:

- Out1 turned On before switch to V1_standby
- V2 active in run mode
- Interrupt mode active
- Wakeup by Iv1 > Icmp_rise

Figure 50. Wakeup form V1_standby in interrupt mode by V1 current monitoring



10 Tips and tricks

10.1 How to clear LIN and INH status bits (SR0, D17, D18)

The bits indicate whether the last wakeup event was caused by activity on the LIN bus or at the INH input (external CAN transceiver). The bits remain set during the entire duration of the active mode and are cleared with the next transition into standby.

If it is required to clear the bits during active mode (in order to detect a LIN or CAN activity), this is possible by a Go_V1_standby command followed by an immediate wakeup by SPI.

10.2 Switch watchdog from window mode to continuous time-out mode (for Flashing of microcontroller)

By sending the command Go_V1_standby with ICMP=1 followed by an immediate wakeup (e. g. by INH or SPI) it is possible to leave the window watchdog mode.

The watchdog will start a Long Open Window (LOWi) which expires after 65ms (nom). If the above sequence is repeated before the LOWi expires it is possible to maintain a continuous time out mode of the watchdog. This procedure can be used for Flash operations if the devices Flash mode cannot be entered by applying a high voltage (>9V) at PWM2.

10.3 Border conditions to be considered when going to standby

10.3.1 Go_V1_standby after 8x watchdog failure

If the watchdog failure counter is 8, a Go_V1_standby command can cause the V1 regulator to be turned Off for 200ms. Depending on the software structure, this can result in a dead-end situation which can be terminated only by a power-on Reset (Vs).

After a watchdog failure (the watchdog failure counter can be read in Status Register 1) the software has to put priority on triggering the watchdog. A Go_V1_standby command with WD failure counter 0 is forbidden.

10.3.2 Go_V1_standby with watchdog failure and INT mode enabled

In Interrupt mode (INT_en = 1), a Go_V1_standby command after a watchdog failure (or a watchdog failure generated in the same communication frame as the Go_V1_standby command) will cause an Interrupt (Dig_out4/INT = high).

A Go_V1_standby command after or together with a watchdog failure is forbidden.

10.4 Consequences of using ICMP bit

- ICMP=1 and INH not connected is not allowed (system deadlock)

- ICMP can be used to run the watchdog in continuous time-out mode (see item 2)

10.5 Recommended setup on unused pins

Table 3. Unused pins recommendation

Pin #	Pin name	SPI configuration	External connection
17	Dig_out3	CR1, D12-D14: if possible, choose configuration which avoids toggling of the output (switching noise)	Open
18	Dig_out4	CR1, D20: INT_EN = 0 (INT mode disabled)	Open
36	FSO	N/A	Open
15 16	PWM1, PWM2	N/A	GND
22 21 20 19	WU1-4	CR1, D0-D3: W0-3 = 1 (input disabled) CR1, D8-11: U0-3 = 0 (default, input configured with current sink in standby)	GND (can be left open if no pcb trace is connected to this pin)
5	INH	N/A	1kΩ to GND
8 9 10 23 24 25	OPV1 OPV2	N/A	Voltage Follower (IN+ = GND, IN- = OUT)
33	LIN	N/A	Open
6	RxD	N/A	Open
7	TxD	N/A	Open
32	LIN_PU	CR2, D06: LIN_PU = 1 (off)	Open
2	V2	CR0, D17-18: Vreg off in all modes	Open
34 35	Rel1, Rel2	Default setting (off)	Open
26 27 28 29 30	OUT1-4, OUT_HS	Default setting (off)	Open

Appendix A L9952GXP software drivers

```
/*****************************************************************************/
/*! Project Name:   L9952 cookbook driver
    @file           L9952drv_cookbook.h
    @brief          SW cookbook driver for ST L9952 device - Configuration file

    Copyright (c) 2008 STMicroelectronics.

    THIS PROGRAM IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED
    OR IMPLIED, INCLUDING BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY
    AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND
    PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU
    ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.
*****************************************************************************/
#define   L9952DRV_COOKBOOK_H
#define   L9952DRV_COOKBOOK_H
#include "L9952drv.h"
#include "Std_Types.h"
/*****************************************************************************
************* Internal Constants and Protypes - application related ************
*****************************************************************************/
#define WU_DEF_HW_VAL  0x000000u
#define HSOL_DEF_HW_VAL0x000000u
#define SETUP_WU_STANDBY  L9952DRV_MASK_OUT1|L9952DRV_MASK_OUT2|L9952DRV_MASK_OUT3 \
                        | L9952DRV_MASK_OUT4|L9952DRV_MASK_OUTHS|L9952DRV_MASK_WU1 \
                        | L9952DRV_MASK_WU2|L9952DRV_MASK_WU3|L9952DRV_MASK_WU4

#define SETUP_WU_STANDBY_VAL  0x00u
#define SETUP_WU1_PULLUPD  L9952DRV_WU_INPUT_MODE_CUR_SOURCE
#define SETUP_WU2_PULLUPD  L9952DRV_WU_INPUT_MODE_CUR_SOURCE
#define SETUP_WU3_PULLUPD  L9952DRV_WU_INPUT_MODE_CUR_SINK
#define SETUP_WU4_PULLUPD  L9952DRV_WU_INPUT_MODE_CUR_SINK
#define SETUP_ONTIME_TIMER2L9952DRV_TIMER2ONTIME_1
#define SETUP_FILTER_DELAY L9952DRV_IN_FILTER_800_TIMER2
#define CYCLIC_SENSE        L9952DRV_OUT_MODE_TIMER1
#define HS_CFG_STDBY        L9952DRV_MASK_OUT2|L9952DRV_MASK_OUT3|L9952DRV_MASK_OUT4
/*****************************************************************************
********************************* Variables **********************************
*****************************************************************************/
extern uint32 WU_Stored_Val;
extern uint32 HSOL_Stored_Val;
```

```
/*****************************************************************************
*********** Internal Constants and Protypes - non-application related **********
*****************************************************************************/
#define POWERON_PROC    0x01u
#define VSTANDBY_TSD2   0x02u
#define V1_SHORTOVERLOAD0x03u
#define V1_MIN2V        0x04u
#define WD_PB           0x05u
#define WKUP_LIN        0x06u
#define WKUP_CAN        0x07u
#define WKUP_WU         0x08u
#define WKUP_HSOL       0x09u
#define UNKNOWN         0x0Au
#define COLD_START      (*StatusReg0 & (uint32)0x080000u)
#define TSD2             (*StatusReg1 & (uint32)0x000010u)
#define NO_RESTART      (*StatusReg1 & (uint32)0x000E00u)
#define V1_FAIL         (*StatusReg1 & (uint32)0x000020u)
#define WD_FAIL          (*StatusReg1 & (uint32)0x00F000u)
#define WAKEUP_LIN      (*StatusReg0 & (uint32)0x040000u)
#define WAKEUP_CAN      (*StatusReg0 & (uint32)0x020000u)
#define WU_DEFAULT      ((*StatusReg0&0x01E000) != (uint32)WU_DEF_HW_VAL)
#define HSOL_DEFAULT    ((*StatusReg0&0x00000F) != (uint32)HSOL_DEF_HW_VAL)
#define WU_STORED       ((*StatusReg0&0x01E000) != (uint32)WU_Stored_Val)
#define HSOL_STORED     ((*StatusReg0&0x00000F) != (uint32)HSOL_Stored_Val)
/*****************************************************************************
******************************** Functions **********************************
*****************************************************************************/
uint8 L9952drv_Go_Standby(L9952drv_StandbyModeType mode);
uint8 L9952drv_PowerOn_Diagnosis(void);
uint8 L9952drv_WakeUp_Diagnosis(void);
#endif
/*****************************************************************************/
/*! Project Name:   L9952 cookbook driver
    @file           L9952drv_cookbook.c
    @brief          SW cookbook driver for ST L9952 device - Configuration file
    Copyright (c) 2008 STMicroelectronics.
    THIS PROGRAM IS PROVIDED "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED
    OR IMPLIED, INCLUDING BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY
    AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND
    PERFORMANCE OF THE PROGRAM IS WITH YOU. SHOULD THE PROGRAM PROVE DEFECTIVE, YOU
    ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.
```

```
*******************************************************************************/
#include "L9952drv_cookbook.h"
#include "timer10ms.h"
#include "timer64us.h"
#include "spi.h"
#include "processor.h"
uint32 WU_Stored_Val = 0x000000u;
uint32 HSOL_Stored_Val = 0x000000u;
uint32 local_statusreg_0;
uint32 local_statusreg_1;
L9952drv_StatusRegType *StatusReg0 = &local_statusreg_0;
L9952drv_StatusRegType *StatusReg1 = &local_statusreg_1;
/*******************************************************************************
********************************** Functions **********************************
*******************************************************************************/
For details on the flowchart of the function L9952drv_PowerOn_Diagnosis, please refer
to the Figure 17 - Power-on diagnosis flowchart.
/*******************************************************************************
! @fn uint8 L9952drv_PowerOn_Diagnosis()
  @brief
When called after the L9952 reset, this module shall initialise the SPI
peripheral of the uC and the the whole L9952 driver, return the reason
of this reset.
*******************************************************************************/
uint8 L9952drv_PowerOn_Diagnosis(void)
{
   SPI_Init();
   L9952drv_Init();
   L9952drv_GetStatus0 (StatusReg0);
   if (COLD_START)
   {
     return POWERON_PROC;                                  // Power-on Procedure
   }
   L9952drv_GetStatus1 (StatusReg1);
   if (TSD2)
   {
      if (!NO_RESTART)
      {
        L9952drv_SetStandbyMode(L9952DRV_STANDBYMODE_VBAT);   // 8*TSD2
        return VSTANDBY_TSD2;
```

```
   }
   return V1_SHORTOVERLOAD;            // TS2 after V1 short/overload
}
if (V1_FAIL)
{
   return V1_MIN2V;                    // V1<2V for t>2us
}
if (WD_FAIL)
{
   return WD_PB;                       // Watchdog trigger problem
}
if (Processor_Check_uC_Poweron())      // needs HW support from uC architecture !
{
   if (WAKEUP_LIN)
   {
      return WKUP_LIN;                 // WAKEUP LIN
   }
   if (WAKEUP_CAN)
   {
      return WKUP_CAN;                 // Wakeup CAN
   }
   if (WU_DEFAULT)
   {
      return WKUP_WU;                  // Wakeup by contact activity
   }
   if (HSOL_DEFAULT)
   {
      return WKUP_HSOL;                // Wakeup by open load change
   }
   return UNKNOWN;                     // Unknown reason for wakeup
}
if (WU_STORED)                        // Soft initialization
{
   return WKUP_WU;                     // Wakeup by contact activity
}
if (HSOL_STORED)
{
   return WKUP_HSOL;                   // Wakeup by open load change
}
```

```
   L9952drv_GetStatus0 (StatusReg0);  // conf. contacts static sense
   if (WU_STORED)
   {
      return WKUP_HSOL;               // Wakeup by contact activity
   }
   return UNKNOWN;                    // Unknown reason for wakeup
}
```

For details on the flowchart of the function L9952drv_Go_Standby, please refer to the Figure 20 - Preparation for standby flowchart.

```
/*****************************************************************************
! @fn void L9952drv_Go_Standby(L9952drv_StandbyModeType mode)
@brief Prepare the L9952 to go into the selected Standby mode
*****************************************************************************/
uint8 L9952drv_Go_Standby(L9952drv_StandbyModeType mode)
{
   uint8 result_diagnosis = 0;
   // Set all inputs to static sense (64us)
   L9952drv_SetInputFilterMode
   (L9952DRV_MASK_WU1|L9952DRV_MASK_WU2|L9952DRV_MASK_WU3|L9952DRV_MASK_WU4,L9952DRV
   _IN_FILTER_64);
   // Turn on supply of contacts (OUT_HS = On)
   L9952drv_SetOutMode (L9952DRV_MASK_OUTHS, L9952DRV_OUT_MODE_ON);
   // wait 64us
   Timer64us_Start();
   while(!Timer64us_Timeout());
   // Read and Store WU input status
   L9952drv_GetStatus0 (StatusReg0);
   WU_Stored_Val = *StatusReg0 & 0x001E000u;
   // Set pull up/down configuration for each input
   L9952drv_SetWUInputMode (L9952DRV_MASK_WU1, SETUP_WU1_PULLUPD);
   L9952drv_SetWUInputMode (L9952DRV_MASK_WU2, SETUP_WU2_PULLUPD);
   L9952drv_SetWUInputMode (L9952DRV_MASK_WU3, SETUP_WU3_PULLUPD);
   L9952drv_SetWUInputMode (L9952DRV_MASK_WU4, SETUP_WU4_PULLUPD);
   // cyclic sense ?
   if ((CYCLIC_SENSE == L9952DRV_OUT_MODE_TIMER1) || (CYCLIC_SENSE ==
       L9952DRV_OUT_MODE_TIMER2))
   {
      // Set ON-time timer2
      L9952drv_SetTimer2 (SETUP_ONTIME_TIMER2);
      // Set filter delay for inputs
```

```
   L9952drv_SetInputFilterMode
   (L9952DRV_MASK_WU1|L9952DRV_MASK_WU2|L9952DRV_MASK_WU3|L9952DRV_MASK_WU4,SETUP
   _FILTER_DELAY);

    // Configure OUT_HS for cyclic mode w/ timer2

   L9952drv_SetOutMode (L9952DRV_MASK_OUTHS, L9952DRV_OUT_MODE_TIMER2);

}

else

{

   // Set all inputs to static sense (64us)

L9952drv_SetInputFilterMode
(L9952DRV_MASK_WU1|L9952DRV_MASK_WU2|L9952DRV_MASK_WU3|L9952DRV_MASK_WU4,L9952DRV
_IN_FILTER_64);

}

//Enable/Disable WU_inputs , Enable/Disable WU by OL

L9952drv_DisableWakeupSource (SETUP_WU_STANDBY, (uint8)SETUP_WU_STANDBY_VAL);

switch (mode) {

 case L9952DRV_STANDBYMODE_V1:

      //Turn off outputs no needed in standby

      L9952drv_SetOutMode (HS_CFG_STDBY, L9952DRV_OUT_MODE_OFF);

      // Set ICMP = 0

      // => ICMP will be set in Library Function 'L9952drv_SetStandbyMode'

      // Open WD window ?

      while(!Timer10ms_IsWdWindowOpen());

      Timer10ms_ResetWDC();

      // Trigger Watchdog

      L9952drv_WdgTrigger();

      //Go to V1_standby

      L9952drv_SetStandbyMode (L9952DRV_STANDBYMODE_V1);

      Processor_Go_To_Standby();

      // return the reason of the wakeup from V1_standby

      result_diagnosis = L9952drv_WakeUp_Diagnosis();

      break;

 case L9952DRV_STANDBYMODE_VBAT:

      //Turn off outputs no needed in standby

      L9952drv_SetOutMode (HS_CFG_STDBY, L9952DRV_OUT_MODE_OFF);

      //Go to VBat

      L9952drv_SetStandbyMode (L9952DRV_STANDBYMODE_VBAT);

     break;

 default:

   #ifdef  L9952DRV_DEV_ERROR_DETECT
```

```
            L9952drv_ReportError (SID_L9952drv_SetStandbyMode,
             L9952DRV_EID_PARAMETER1_OUT_OF_RANGE);

         #endif

      }

      return result_diagnosis;

}

/*****************************************************************************

! @fn uint8 L9952drv_WakeUp_Diagnosis()

@brief

When called after the uC wakes up from V1_standby, this module shall return the
reason of this wakeup (CAN or LIN).

*****************************************************************************/

uint8 L9952drv_WakeUp_Diagnosis(void)

{

   L9952drv_GetStatus0 (StatusReg0);

   if (WAKEUP_LIN)

   {

      return WKUP_LIN;                          // WAKEUP LIN

   }

   if (WAKEUP_CAN)

   {

      return WKUP_CAN;                          // WAKEUP CAN

   }

   return UNKNOWN;                              // Unknown reason for wakeup

}
```

Appendix B L9952GXP information summary

Table 4. L9952GXP information summary

N°	Function	Reference	Information
1	Diagnosis	CLR	Clear-bit (D21, CR 1): clears content of both Status Registers at CSN low-to-high; actual status is transfered during the CLR frame; subsequent failure events are inserted in SR and are read at next communication frame; Status registers should be read again after CLR command in order to verify if failure is still present (in this frame, CLR should be set to 0 in order to ensure that status is not cleared by accident with next write command to CR1)
2	Diagnosis	OL/OC	OL and OC diagnosis with 64 µs filter, failure bit is latched also when driver turned Off or companion in standby mode. Outputs turn-on after CLR command. In autorecovery mode (only OUT_HS), failure bit is cleared automatically and driver is turned On
3	Diagnosis	OL/OC	OL is detected in ON state, status is latched until CLR command
4	Diagnosis	TSD	Thermal shutdown: TW: pre-warning; TW-bit set (D2 SR 1), bit latched until CLR TSD1:TSD1 bit set (D3, SR1); all outputs except V1 latched off until CLR TSD2: TSD2 bit set (D4, SR1); V1 turned Off for 1 sec
5	Diagnosis	Vs OVUV	Vs Over- / Undervoltage: OV or UV bit is set; outputs are turned Off and will re-start automatically; outputs can be latched off by SPI (turn-on after CLR command); UV/OV turn-off can be disabled for LS outputs
6	Diagnosis	Vs OVUV	Vs OV/UV: Vs-lockout, no NReset, register settings remain; OV: all outputs highZ, OV bit is set, over voltage lockout (outputs are turned On according to register settings when fail bit cleared by SPI) or autorestart (drivers turned On according to register settings as soon as Vs below OV threshold) UV: all outputs turned Off, UV bit is set, under voltage lockout (outputs are turned On according to register settings when fail bit cleared by SPI) or autorestart (drivers turned On according to register settings as soon as Vs above UV threshold)
7	Diagnosis	Vx fail	V1fail and V2 fail bits: set in case of voltage < 2V for > 2 µs (temporary voltage drop) or at power-on if voltage < 2V after 4ms (short circuit detection) Short circuit detection: ==> Forced Vbat_standby in case of V1 short (to avoid thermal cycling at static short circuit); wakeup is by any wakeup source ==> V2 turned Off in case of V2 short (to avoid thermal cycling at static short circuit); SHT5V2 bit (D12, SR0) is set
8	Diagnosis	Vx fail	Short at V1 at turn-on: if V1<2V after 4ms ==> Vbat_standby; wakeup is by any WU source
9	Diagnosis	Vx fail	Short at V2 at turn-on: if V2<2V after 4ms ==> V2 turned Off; latched until CLR

Table 4. L9952GXP information summary (continued)

No	Function	Reference	Information
10	Outputs	OL/OC	Auto-recovery mode: needs to be limited in time in order to reduce thermal stress
11	Outputs	OL/OC	Auto-recovery mode: OC flag is set when overcurrent is reached, flag is cleared at auto-restart
12	Outputs	OL/OC	Auto-recovery mode: automatic turn-on after detection of overcurrent; OC flag is cleared at auto-restart until next OC condition; other failures (overtemperature etc.) are still recognized
13	Outputs	WD	Outputs can be turned On during 'long open window' (before WD trigger) if no watchdog failure occured previously
14	Outputs	WD	After watchdog failure the outputs are latched off; turn-on is possible only after valid watchdog trigger; watchdog trigger and output control is possible within the same SPI frame
15	Outputs	WD	Low side control bits are cleared after watchdog failure; High Side Control Bits are not cleared
16	Reset	POR	Power-on-reset: at Vpor threshold (3.45 V typical), registers are set to '0', Cold start (D19, SR0) is set to '1' and can be read only with the first SPI access. Any valid SPI access (24 falling edges on CLK during CSN = low) will clear Cold Start flag
17	Reset	V1_standby	At wakeup from V1_standby mode without Nreset (wakeup by INH, LIN, SPI, Iv1 or wakeup with INT_en = 1), the Nreset is blocked for 2ms after wakeup ==> a watchdog failure during 2ms after wakeup does not cause a NReset generation but outputs are switched off and FSO is activated
18	Reset	V1_standby	Watchdog Started by Iv1 > Icmp_rise: wakeup event during Long Open Window (before WD trigger) does not cause a Nreset, Watchdog is not restarted, trigger bit must be inverted
19	SPI	Clock Monitor	SPI clock monitor: counts number of clock cycles in one SPI frame during regular communication (while CSN is low); frame should contain 24 clock pulses; in case of failure the frame is ignored
20	SPI	Mode	SPI mode: CPOL=0, CPHA=0, input data is sampled at rising edge, output data is shifted out at falling edge
21	Standby modes	Forced Vbat	Forced Vbat_standby after multiple watchdog failures (8+7): V2 remains On if configured 'ON in all modes'. Watchdog failure counter is set to 0 when forced Vbat_standby is entered Forced Vbat_standby after 8x TSD2: V2 is Off (even if configured 'ON in all modes'); TSD2 (D04, SR1) is set and prevents turn-on of outputs
22	Standby modes	ICMP	ICMP = 1: device enters standby and watchdog is disabled regardless of Iv1. However, voltage regulator remains in high current mode if Iv1 > Icmp_fall (increased quiescent current)
23	Standby modes	ICMP	V1 Current threshold: all currents at logic outputs (especially FSO) are derived from V1, i. E. Icmp is sum of Iv1 plus currents at all logic pins
24	Standby modes	Outputs	before going to standby mode, the outputs should be turned Off (in order to avoid turn-on of the outputs in case of unwanted wakeup)

Table 4. L9952GXP information summary (continued)

No	Function	Reference	Information
25	Standby modes	SPI	If both standby-bits are set (Go_Vbat CR0 D20 and Go_V1 CR0 D21), the device will enter Vbat_standby mode
26	Standby modes	V1_standby	Go_v1 bit (D21, CR0) is reset immediately when L9952 enters standby
27	Standby modes	watchdog	device enters standby mode after standby command but WD expects trigger (within regular window) until Iv1<1mA. ==> uC has to reduce Iv1 within 16ms(nom), otherwise, watchdog expects trigger signal and generates NReset. If Iv1 was below 1mA and is then increasing above 1mA, WD is activated and starts with Long Open Window. Recommendation: send standby command and last watchdog trigger within one frame (CR0)
28	Voltage Regulator		V1: L9952 turns-off V1 in case of a) 7 watchdog failures in sequence (off for 200ms) b) TSD2 (enters forced Vbat_standby; wakeup by any wakeup event)
29	Voltage Regulator		In Vbattstandby mode, the regulator output is pulled to GND. Output capacitors are discharged
30	Wakeup	LIN INH	Wake up by LIN or INH: SR0, D17/D18 indicates wakeup source; bits are latched until next standby and cannot be cleared by CLR Go_V1 command and wakeup by SPI can be used to clear LIN and INH status bits if required
31	Wakeup	SPI	Wakeup by SPI: at CSN high-low and first edge of clock signal, the companion will wake up; not possible from Vbat_standby mode
32	Wakeup		Wake up via INH (CAN) and LIN cannot be disabled and do not generate a reset pulse at NRESET
33	Wakeup		Wakeup inputs are also active in Active mode, i. e. WU inputs can be used to monitor input status in Active mode. Inputs must be configured to 'static sense' in CR2
34	Wakeup		WU by HS open-load: Change of open-load status will cause wakeup; In cyclic mode, OL is measured in ON phase ==> wakeup occurs at beginning of next ON phase; if open-load disappears before next ON phase ==> no wake up occurs;
35	Watchdog	Failure counter	WD0-3 (D12-15, SR1): cleared at every valid watchdog trigger and when forced Vbat_standby is entered a) Watchdog must be triggered successfully before standby mode, i. E. Standby at WD-fail-counter unequal 0 is not allowed b) After wakeup from forced Vbat_standby, outputs are not latched off due to watchdog failure and control bits for HS drivers are not reset
36	Watchdog	ICMP	If ICMP = 1 (D20, CR2): current comparator at V1 remains active but it is not used to enable/disable the watchdog ==> V1stdby mode is entered after standby command and watchdog is disabled regardless of Iv1. Voltage regulator remains in high current mode (increased quiescent current). The ICMP-bit (D21 CR 2) is not cleared automatically

Table 4. L9952GXP information summary (continued)

No	Function	Reference	Information
37	Watchdog	ICMP	ICMP (D20 CR 2) must be set to '0' whenever device goes into Standby mode. This is necessary because bit could be set accidentally ==> companion goes to standby ==> watchdog is disabled independent of uC current consumption ==> fail-safe feature is disabled
38	Watchdog	ICMP	If V1_standby mode and watchdog active due to Iv1 > Icmp: a watchdog failure is not a wakeup event, after 15 watchdog failures in sequence the device will go to Vbat_standby mode
39	Watchdog	LOWi	Watchdog starts with 'Long Open Window' (LOWi) after a) Power-on (Vs) b) NReset event (Watchdog Failure) c) Wakeup from standby d) Exit from Flash mode writing to CR0 without inverting TRIG (D19, CR0) has no effect on watchdog
40	Watchdog	LOWi	TRIG must be inverted to terminate LOWi and enter window mode If LOWi started after Nreset (i. E. After watchdog failure or wakeup from Vbat_standby) TRIG is set to '0' and must be set to '1'
41	Watchdog		1) After each valid watchdog trigger (bit inverted), the watchdog will immediately continue with a closed window followed by an open window 2) Writing to the trigger bit during a closed window: - not inverting trigger bit has no effect (no NReset) - inverting the trigger bit will cause a NReset (early write) 3) Writing to trigger bit during open window: - not inverting trigger bit has no effect (no NReset) - inverting trigger bit is a valid watchdog trigger, next closed window is started immediately 4) Watchdog starts with a long open window after any wakeup or NReset event or exit from Flash mode

Reference documents

Table 5. Reference documents

Document name	Documents link
L9952GXP Datasheet	http://www.st.com/stonline/stappl/productcatalog/app?path=/pages/stcom/PcStComPartNumberSearch.searchPartNumber&search=l9952gxp*
L9952GXP Driver User Manual	

Revision history

Table 6. Document revision history

Date	Revision	Changes
18-Jul-2008	1	Initial release.
24-Sep-2013	2	Updated disclaimer.