Application Note TLE9252V

Diagnostics via NERR pin

About this document

Scope and purpose

This document provides application information for the transceiver TLE9252V from Infineon Technologies AG as Physical Medium Attachment within a Controller Area Network (CAN).

This document contains information about:

- Diagnostics via NERR output pin

This document refers to the data sheet of the Infineon Technologies AG CAN Transceiver TLE9252V.

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

Intended audience

This document is intended for engineers who develop applications.

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1 TLE9252V Description

The transceiver TLE9252V represents the physical medium attachment, interfacing the CAN protocol controller to the CAN transmission medium. The transmit data stream of the protocol controller at the TxD input is converted by the CAN transceiver into a bus signal. The receiver of the TLE9252V detects the data stream on the CAN bus and transmits it via the RxD pin to the protocol controller.

1.1 Features

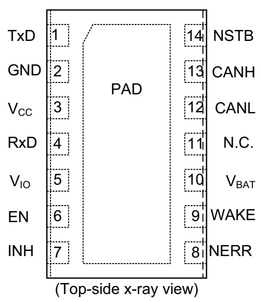
The main features of the TLE9252V are:

- Baud rate up to 5Mbit/s for CAN FD and 1Mbit/s for Classical CAN
- Very low Electromagnetic Emission (EME) and high Electromagnetic Immunity (EMI)
- Excellent ESD performance according to HBM (+/-10 kV) and IEC (+/-8 kV)
- Bus wake-up and Local Wake-up (see **Chapter 2.1**)
- INH output pin to control external circuitry
- Local Failure Detection: V_{CC} (see **Chapter 2.3.1**), TxD dominant time-out feature (see **Chapter 2.3.2**), RxD Recessive Clamping Detection (see **Chapter 2.3.3**)
- Very low current consumption in Stand-by and Sleep Mode
- Control input levels compatible with 3.3 V and 5 V devices
- Advanced diagnostics via NERR output pin (see **Chapter 2**)
- Thermal shutdown protection

1.2 Mode Description

The TLE9252V supports four different modes of operation. The mode of operation depends on the status of the power supply voltages V_{CC}, V_{IO} and V_{BAT} and the status of the mode selection pin NSTB and EN:

- Normal-operating mode: Used for communication on the CAN bus. Transmit and receive data on the bus.
- Receive-only mode: Allows diagnostics, to check modules connections or to avoid communication errors on the bus due to microcontroller failure. Blocking babbling idiots from disturbing communication. Used for Pretended Networking to set ECU and microcontroller to low-power mode, waiting for a specific message to switch to Normal-operating mode.
- Stand-by mode: Interim Mode with reduced current consumption after Power On Reset or after a wake-up occurred and the ECU ramps up. A wake-up event via CAN bus or Local Wake-up is indicated on the RxD and NERR output pin.
- Sleep Mode: Low-power mode of TLE9252V with optimized very low current consumption. INH pin is High-Z in order to switch off the connected voltage regulators. Sleep Mode is used when the ECU is disabled or in Low power mode in order to save battery current.



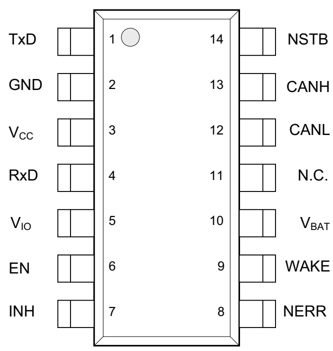


Figure 1 Pin Configuration of the TLE9252V

2 Diagnosis-Flags at NERR pin

TLE9252V offers various diagnosis possibilities, which can be read out via NERR and RxD output pin. **Table 1** shows the status of these pins depending on mode of operation and possible events.

Table 1 Diagnosis-Flags at NERR and RxD

NSTB	EN	INH	Mode	Event	NERR[1)]	RxD[1)]
1	1	V_{BAT}	Normal-operating	No failure detected	1	"Low": bus dominant, "High": bus recessive
				• V_{CC} undervoltage • Overtemperature • TxD time-out • RxD recessive clamping	0	
1	0	V_{BAT}	Receive-only	No failure detected	1	"Low": bus dominant, "High": bus recessive
				• Power-Up-Flag[2)] OR • V_{CC} undervoltage	0	
0	1	V_{BAT}[3)]	Go-to Sleep Command	WUP detected	0	0
				LWU detected	1	0
				No Wake-up event detected	1	1
0	0	V_{BAT}	Stand-by	WUP detected	0	0
				LWU detected	1	0
				No Wake-up event detected	1	1
0	0	High-Z	Sleep	No Wake-up event detected	1	1
				No Wake-up event detected if $V_{IO} < V_{IO\_UV}$	0	0

1) Only valid if V_{IO} is in the functional range.

2) Power-Up flag only available if V_{BAT} or V_{CC} is in the functional range for at least t_{PON}. Power-Up flag will be cleared when entering Normal-operating mode.

3) INH is connected to V_{BAT} if $t < t_{SLEEP}$. If t_{SLEEP} expires and no wake-up is pending and POR Flag is reset, the device enters Sleep Mode and INH is "High-Z".

2.1 Wake-up Flags

In Stand-by Mode and Go-to Sleep Command a wake-up event is indicated on the RxD and NERR output pin. There are two possible wake-up events:

- Wake-up pattern via CAN bus communication: WUP
- Wake-up via Local Wake-up input pin: LWU

If a wake-up event occurs, the RxD pin goes "low". Depending on the wake-up source (CAN bus or Local Wake-up) the NERR is "high" (Local Wake-up) or "low" (CAN Bus wake-up). This offers the opportunity to distinguish between those two wake-up events directly after wake-up of the ECU and microcontroller. Depending on the Wake-up event, the microcontroller can decide how to proceed in the software flow. The INH output pin is switched on when a wake-up event is detected.

A CAN bus wake-up event has higher priority than a Local Wake-up event. Once a wake-up event via CAN bus has been detected, RxD and NERR remain logical "low" in Stand-by Mode and Go-to-Sleep Command.

2.1.1 Wake-up detection in Sleep Mode

If in Sleep Mode V_{IO} is switched off ($V_{IO} < V_{IO\_UV}$), e.g. by controlling a voltage regulator by INH, RxD and NERR are “low”. If a wake-up event is detected (WUP, LWU), this triggers a mode change from Sleep Mode to Stand-by Mode. If a valid wake up pattern (WUP) is detected, RxD and NERR will stay “low” (see **Figure 6**). If a local wake-up (LWU) is detected the RXD will stay “low” and NERR will go “high” (see **Figure 9**). If both, LWU and WUP have been detected, then the WUP detection has higher priority and RxD and NERR pin are set to logical “low”, regardless if a LWU event is pending (see **Figure 2**). When entering Stand-by Mode from Power On Reset, NERR pin and RxD pin are set to logical “high” (see **Figure 10**).

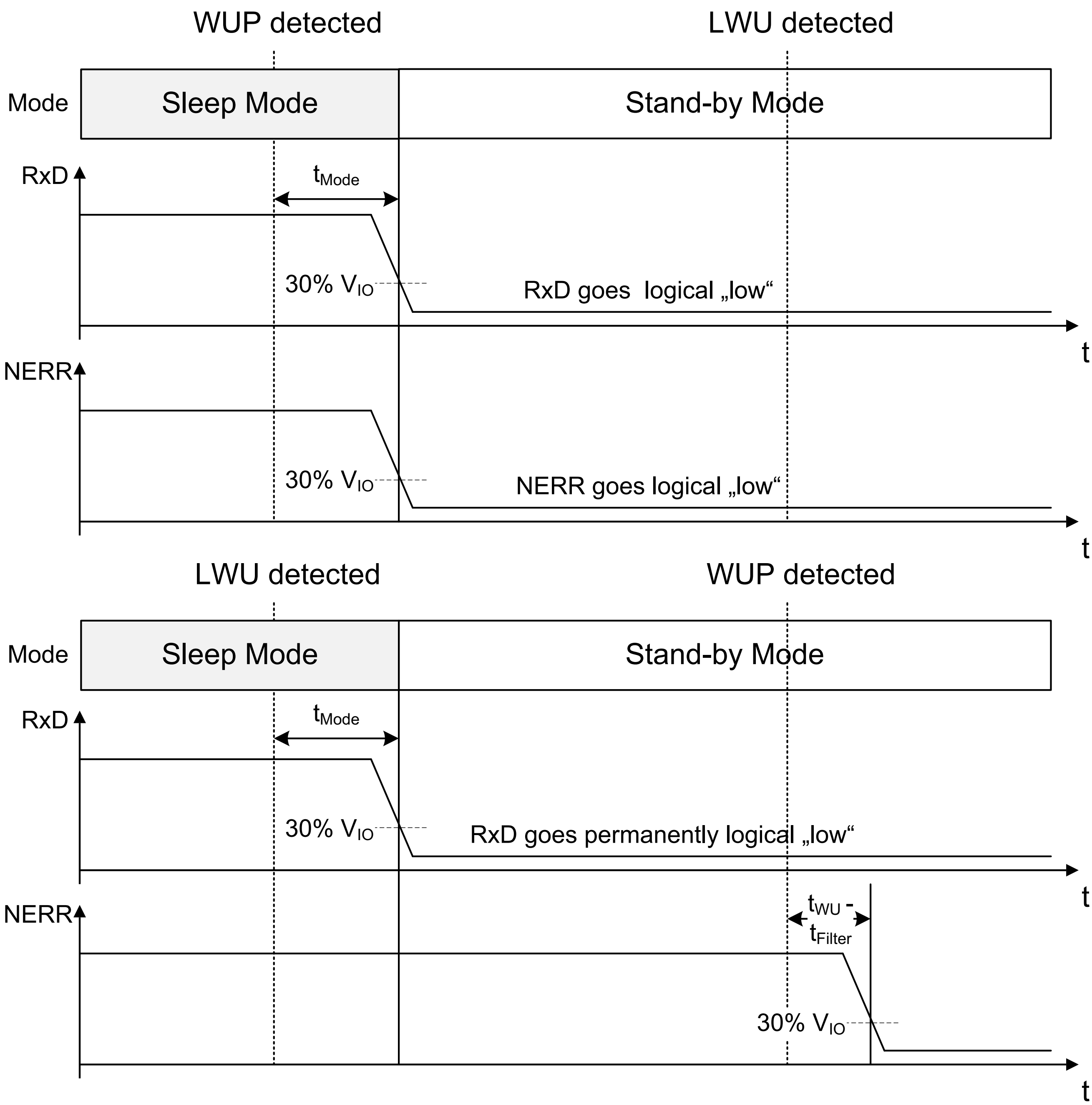


Figure 2 RxD and NERR: WUP AND LWU detection (permanently supplied V_{IO})

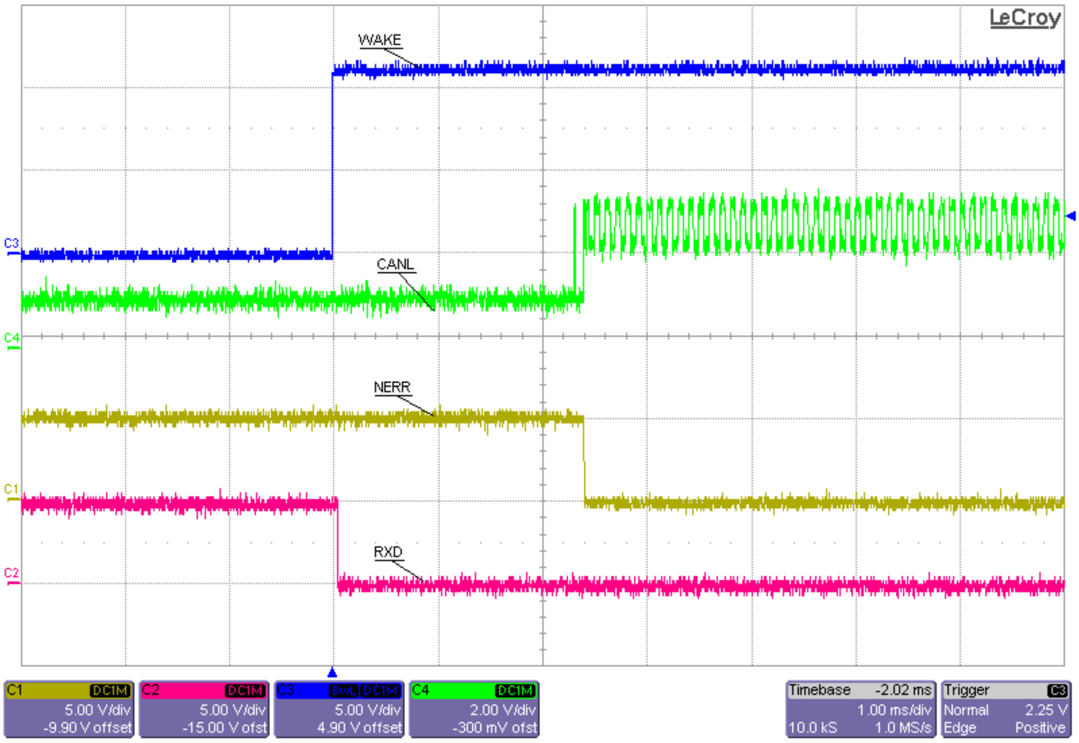


Figure 3 Example Measurement: Local Wake-up followed by Bus Wake-up in Sleep Mode

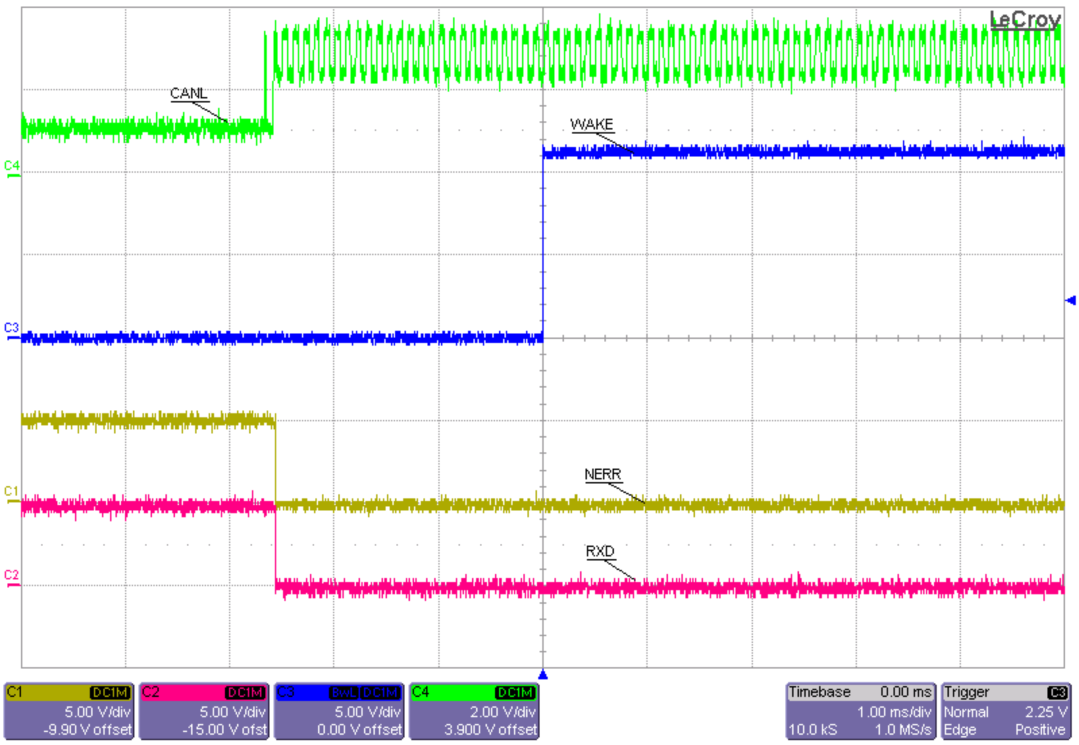


Figure 4 Example Measurement: Bus Wake-up followed by Bus Wake-up in Sleep Mode

The INH pin is disabled in Sleep Mode and connected to battery voltage in Stand-by Mode. This behavior of the INH pin can be used to switch on an external component e.g. voltage regulator (see **Figure 5**). As the INH pin is a battery supplied pin it is important to ensure the input pin of the external component is capable to operate with battery supply.

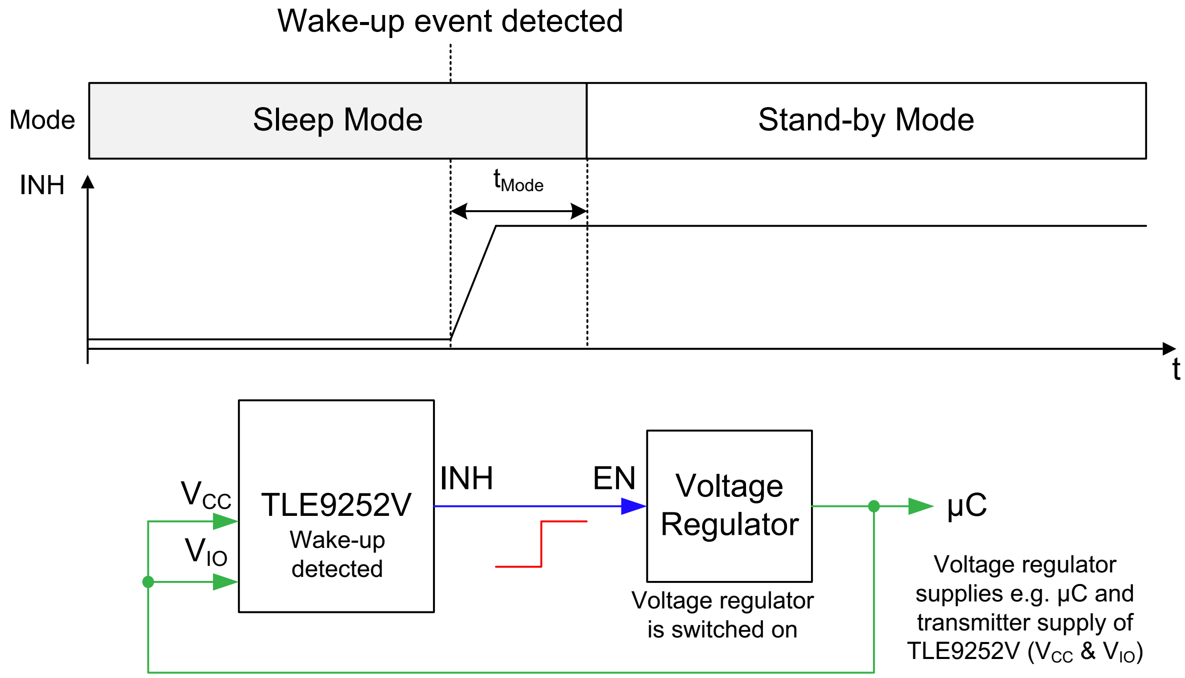


Figure 5 Wake-up detection: INH pin

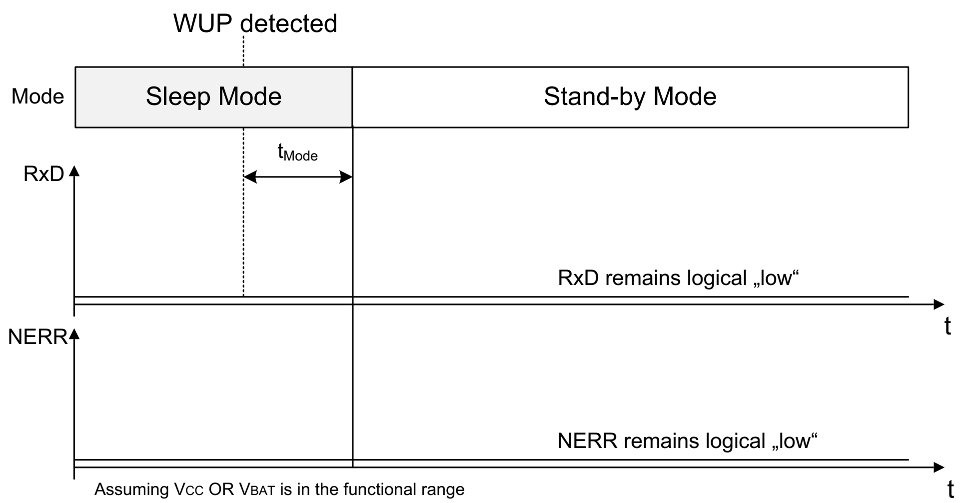


Figure 6 RxD and NERR: WUP detection (V_{IO} not supplied)

Diagnosis-Flags at NERR pin

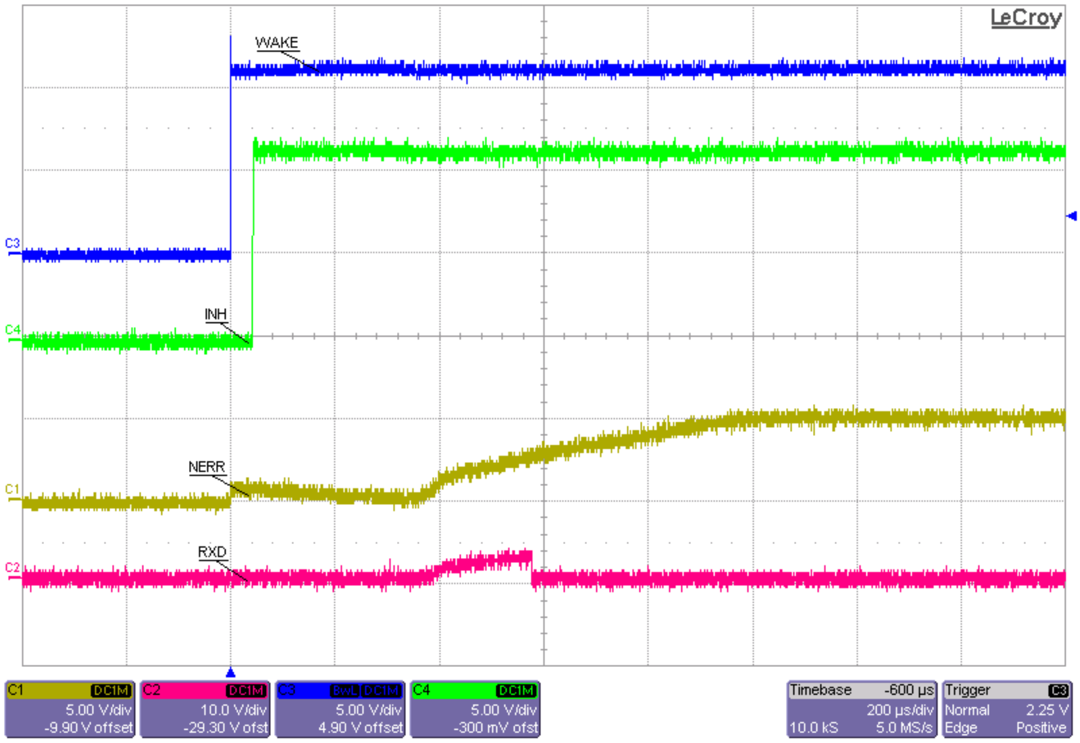


Figure 7 Example Measurement: Local Wake-up event

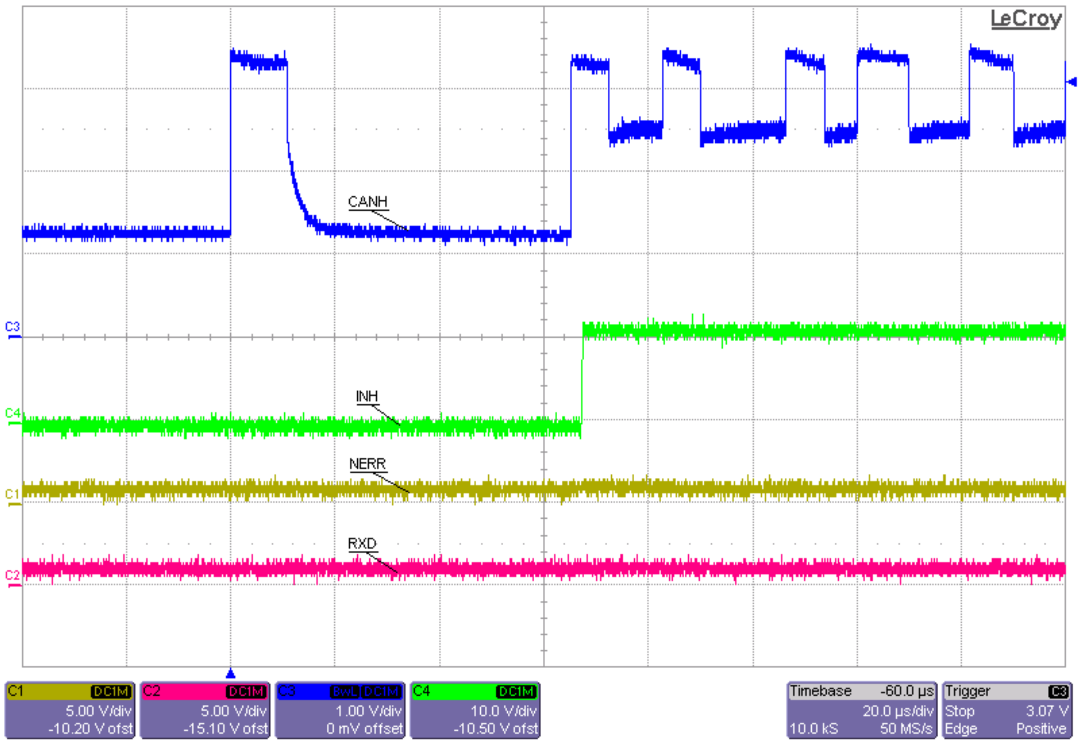


Figure 8 Example Measurement: Bus Wake-up event

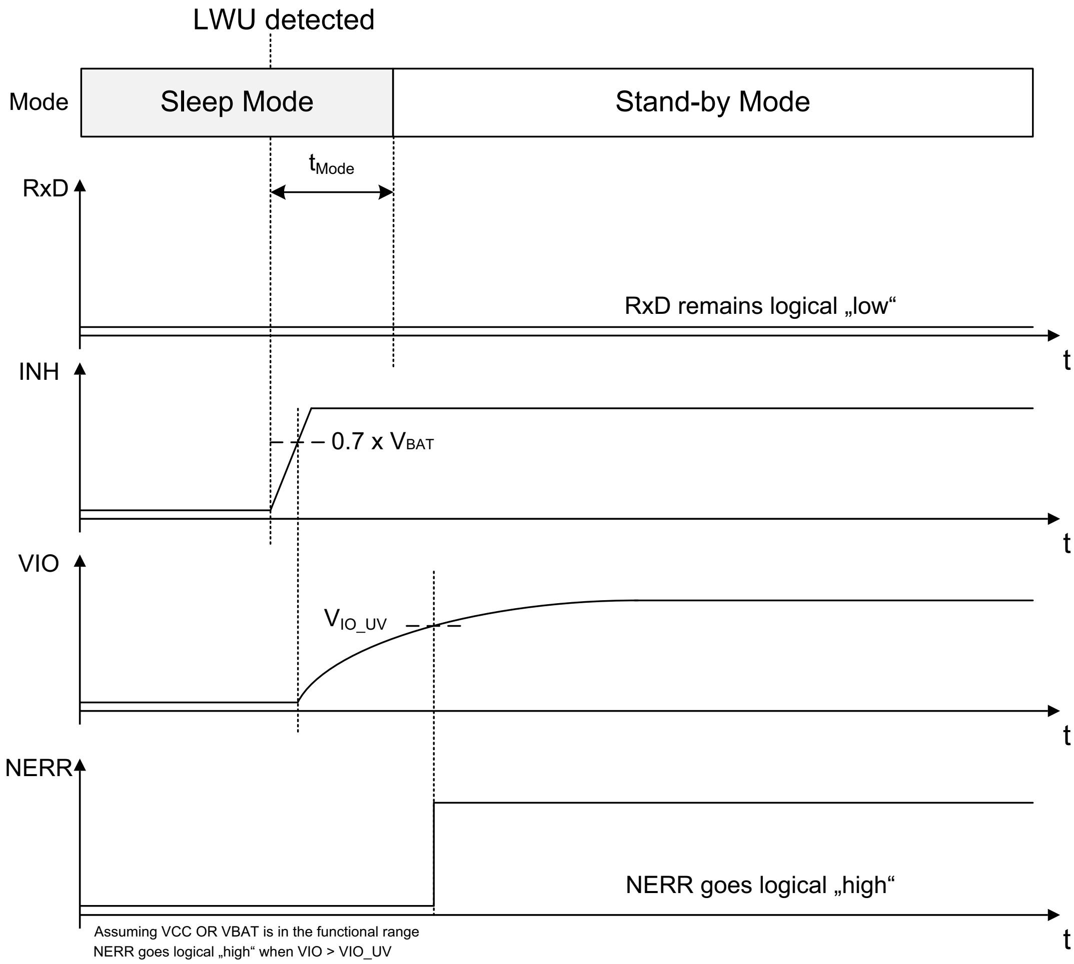


Figure 9 RxD and NERR: LWU detection (V_{IO} not supplied in Sleep Mode)

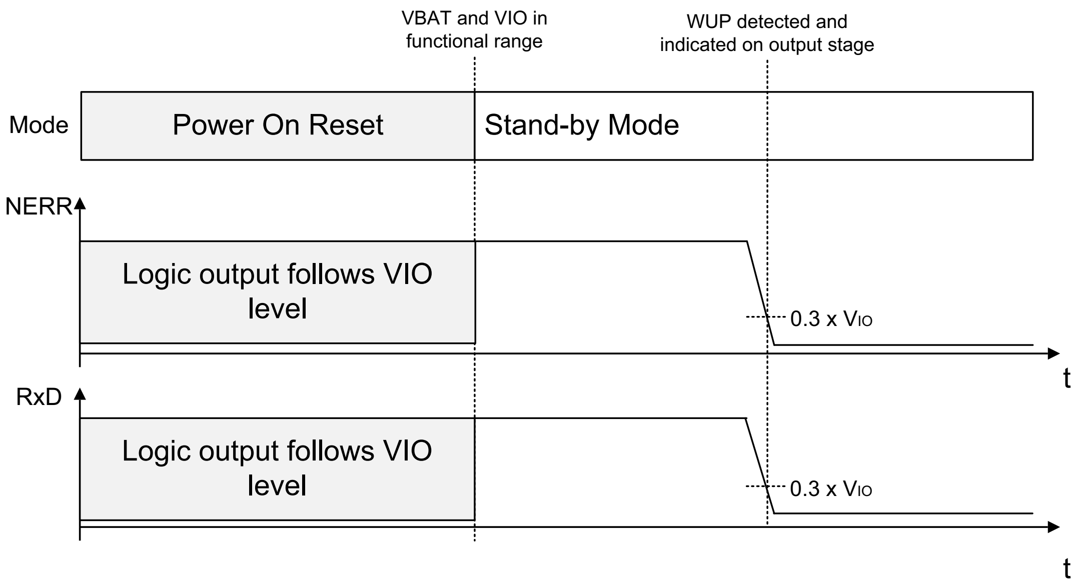


Figure 10 NERR and RxD behavior when entering Stand-by Mode from Power-On-Reset

2.2 Power On Reset Flag (POR Flag)

After first power-up of TLE9252V (connecting V_{BAT} or V_{CC}) the Power On Reset (POR) Flag is set. This Flag can be read out via NERR pin in Receive-only Mode, when coming from Stand-by Mode or Sleep Mode. The POR Flag is reset once the Normal-operating Mode is entered. This Flag offers the possibility to distinguish whether the device has been woken-up by wake-up event or by first power-up of the device.

2.3 Local Failure Flags

Local Failure Flags are indicated on the NERR output pin in Normal-operating Mode and Receive-only Mode. There are four different kind of local failures:

- V_{CC} undervoltage
- TxD "dominant" time-out
- RxD recessive clamping
- Overtemperature

If one of the local failures occurs, the transmitter of the TLE9252V is disabled in order not to block or disturb the CAN communication. In case one of the above mentioned local failures is present, the NERR pin is set to "low" in order to indicate to the microcontroller the transmitter is disabled. If the transmitter is disabled, the CAN node cannot send any message to the HS CAN bus. However the receiver is still active and the CAN node is able to receive messages. A local failure indicates a failure on ECU level occurred, which means the ECU has to be replaced or repaired. For better root cause evaluation of the local failure, using the TLE9252V it is possible to distinguish which local failure occurred. This can be implemented by appropriate software handling, setting the TLE9252V into different mode of operation (see **Figure 11**).

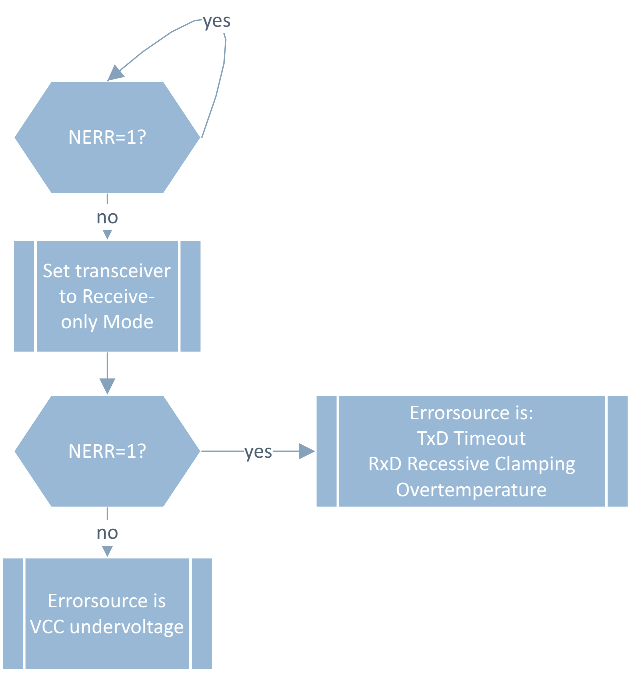


Figure 11 Example Diagnosis Evaluation Path for Local Failures

2.3.1 V_{CC} undervoltage Flag

If in Normal-operating Mode and in Receive-only Mode V_{CC} drops below V_{CC_UV} for t > t_{VCC_filter} the NERR pin goes "low" to indicate an undervoltage event on V_{CC}. In Normal-operating Mode the transmitter is disabled in order to prevent corrupted data transmission to the CAN bus. If the V_{CC} voltage recovers (V_{CC} > V_{CC_UV} for t > t_{VCC_filter} + $t_{VCC\_Recovery}$) the NERR pin is set to "high" in order to signal to the microcontroller the transmitter is enabled again. For differentiation of the four possible local failures, in Receive-only Mode only the V_{CC} undervoltage is flagged on the NERR output pin. In this case the ECU is able to distinguish if a V_{CC} undervoltage is the reason for disabling the transmitter in Normal-operating Mode (Example software flowchart see **Figure 11**).

If the V_{CC} undervoltage event lasts for longer than $t_{VCC\_UV\_T}$ AND no communication was monitored on the CAN bus for longer than $t_{Silence}$ the TLE9252V will go to Sleep Mode in order to save battery current. Possible route cause of V_{CC} undervoltage is a short circuit of V_{CC} to GND. In order to save current an automated transition to Sleep Mode is implemented.

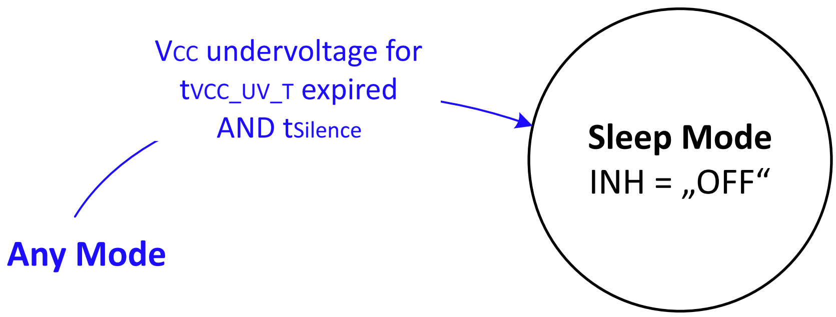


Figure 12 Automatic mode change to Sleep Mode in case of a V_{CC} undervoltage event

Common devices on the market perform an automated mode change to Sleep Mode in case of a VCC undervoltage disregarding if there is communication on the CAN bus or not. Once the device goes to Sleep Mode it wakes up and goes to Stand-by Mode. As a result, common devices on the market toggle between Sleep Mode and Stand-by Mode if there is V_{CC} undervoltage and communication on the Bus. This results in a permanent switching of the bus biasing which affects the bus signal integrity and degrades the EME. Additionally due to the repetitive ramp-up and ramp-down of the voltage regulator and the connected capacitors, the total current consumption is higher.

In order to avoid such a behavior, Infineon's new TLE9252V performs an automated mode change due to V_{CC} undervoltage to Sleep Mode only if there is no communication monitored on the CAN bus for t > $t_{Silence}$ (see **Figure 13**). In low-power mode (Sleep Mode, Stand-by Mode) the bus biasing is enabled depending on bus communication in order to improve the bus signal integrity and EME. Because of no repetitive mode change from Sleep Mode to Stand-by Mode to Sleep Mode the communication on the bus is not affected. Additionally the microcontroller stays supplied as long as communication is monitored on the CAN bus. This means the ECU will not be disconnected from communication and the microcontroller remains the master of voltage supply. The V_{CC} undervoltage is indicated on the NERR output pin to signal a local failure to the microcontroller.

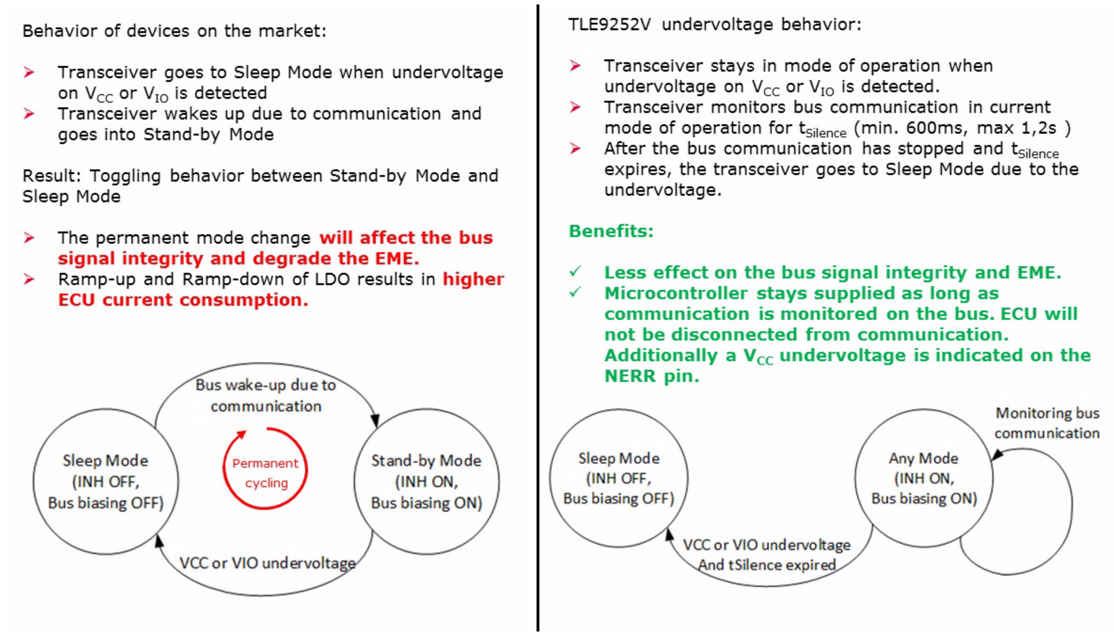


Figure 13 Benefit of TLE9252V V_{CC} undervoltage behavior

2.3.2 TxD Dominant Time-out Flag

In case the TxD-Pin is permanently "low" due to a software error or shorted to GND the TxD dominant time-out detection of TLE9252V protects the CAN bus from being permanently driven to dominant level. When detecting a TxD dominant time-out, the TLE9252V disables the transmitter in order to release the CAN bus (see **Figure 15**). Without the TxD dominant time-out detection, a CAN bus would be clamped to the dominant level and therefore would block any data transmission on the CAN bus.

The TxD dominant time-out detection can be reset after a dominant to recessive transition at the TxD pin. A "high" signal must be applied to the TxD input for at least $t_{TXD\_release}$ = 200 ns to reset the TxD dominant timer (see **Figure 14**).

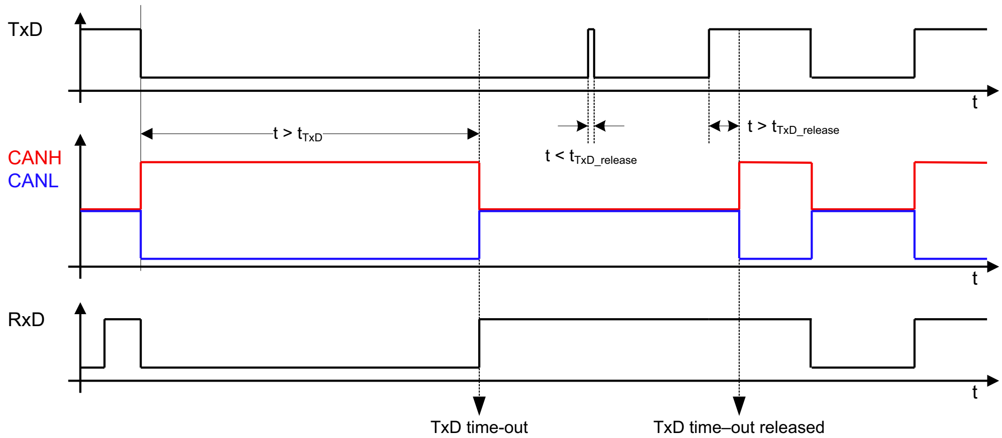


Figure 14 Resetting TxD Dominant Time-out Detection

Diagnosis-Flags at NERR pin

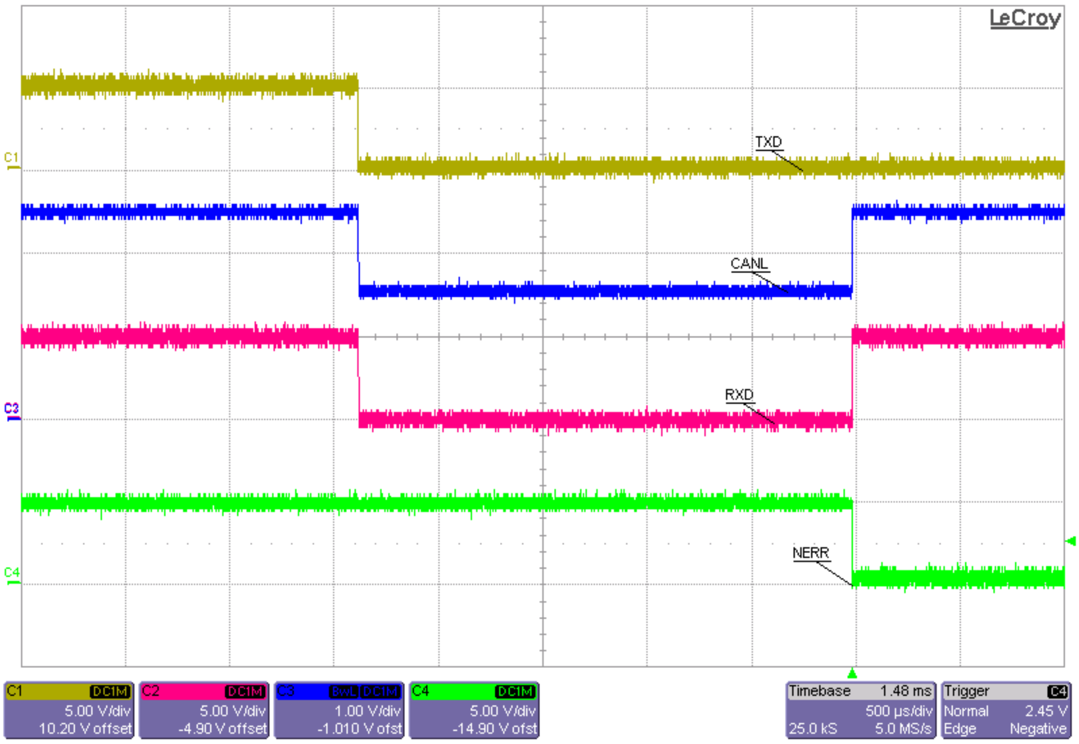


Figure 15 Measurement: TxD Dominant Time-out Detection

In Normal-operating Mode the TxD "dominant" time-out function is enabled. If the input signal on TxD is "low" for t > t_{TXD_TO} the transmitter stops sending a "dominant" signal to the bus in order not to block permanently the communication on the CAN bus. If a TxD "dominant" time-out is detected the NERR is set to "low" in Normal-operating Mode. In Normal-operating Mode if TxD is set to "high" again the NERR goes "high" again to reflect the TxD "dominant" time-out failure disappeared.

If a TxD dominant time-out is detected in Normal-operating Mode the NERR is "low" for a minimum time of $t_{NERR\_TXD\_TO\_LATCH}$ even if the TxD input signal changes to "high" again in order to avoid glitches on NERR pin (see **Figure 16**).

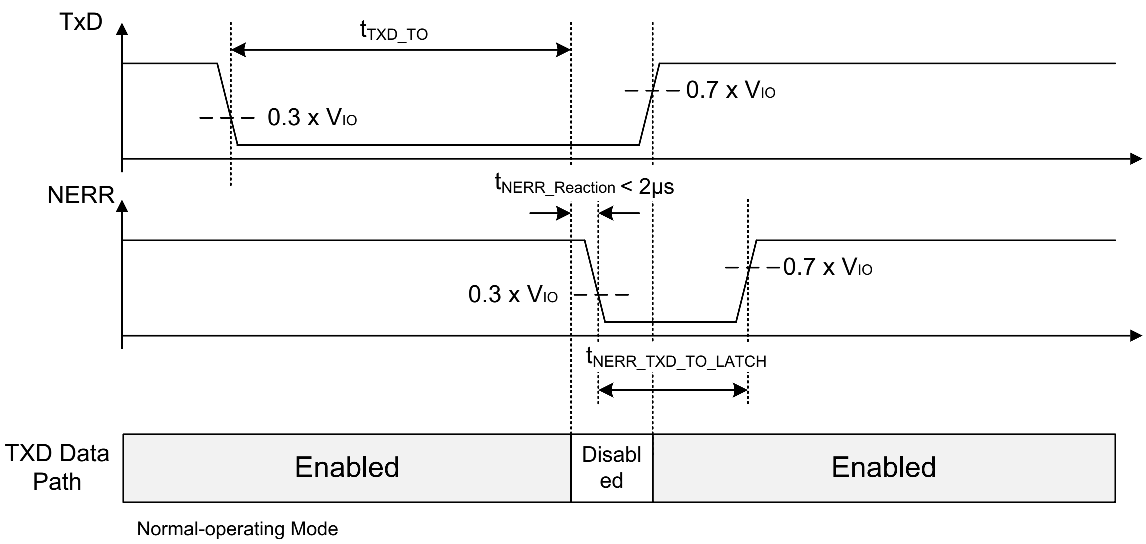


Figure 16 NERR Behavior during short TxD dominant time-out detection

2.3.3 RxD Recessive Clamping Flag

The RxD Recessive Clamping detection is only active in Normal-operating Mode. In Normal-operating mode a permanent logical "high" signal on the RxD pin indicates the external microcontroller, there is no communication on the HS CAN bus. In case the logical "high" signal on the RxD pin is caused by a a failure, like a short circuit RxD to V_{IO}, the RxD signal does not reflect the signal on the HS CAN bus. In this case the microcontroller is able to place a message on the CAN bus at any time and corrupts the CAN messages on the bus. If the TLE9252V detects a logical "high" signal on the RxD pin while the bus is dominant for t > t_{RRC} the RxD Recessive Clamping flag is set. On detection of a RxD Recessive Clamping the transmitter is disabled immediately, so that the corrupted, non-synchronized node is prevented from disturbing the remaining bus traffic. The NERR pin is set to "low" to indicate a local failure in Normal-operating Mode. Whenever the RXD is "low" while the bus signal is "dominant" for t > t_{RRC} the RxD Recessive Clamping flag is reset along with enabling the transmitter in Normal-operating Mode and setting the NERR pin to "high" again.

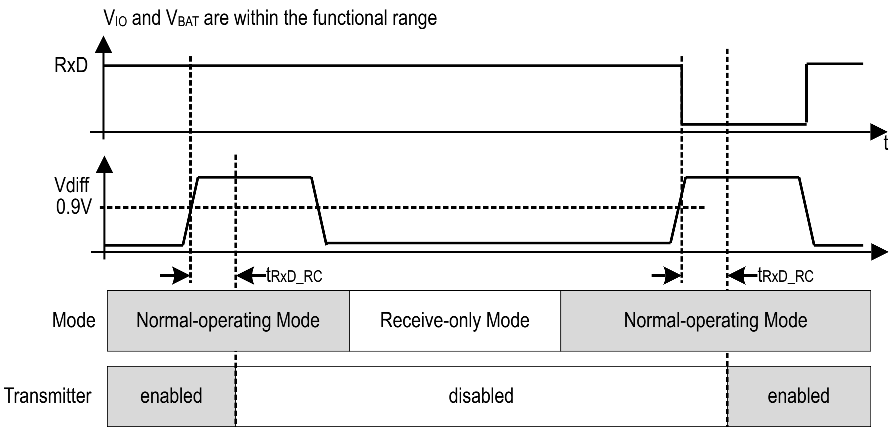


Figure 17 RxD Recessive Clamping impact on Transmitter output stage

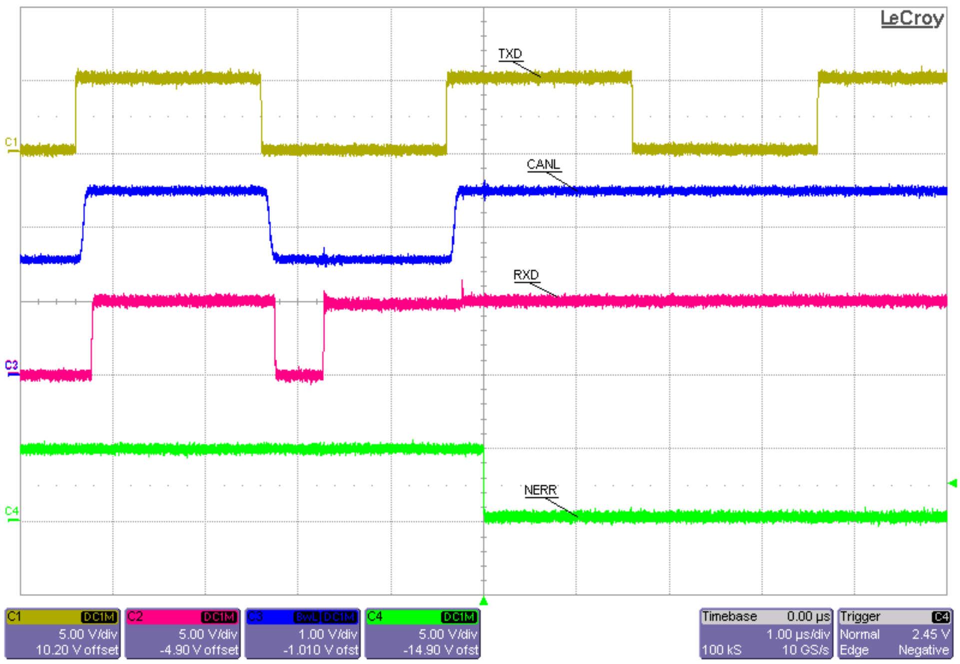


Figure 18 Example Measurement: RxD Recessive Clamping in Normal-operating Mode

2.3.4 Overtemperature Flag

The TLE9252V has an integrated overtemperature detection to protect the TLE9252V against thermal overstress of the transmitter. The overtemperature protection is only active in Normal-operating Mode. When the temperature exceeds the threshold T_{JSD} the transmitter is disabled. This overtemperature event will be signaled as logical "low" on the NERR output pin in Normal-operating Mode. After the device has cooled down, the transmitter is re-enabled and NERR returns to logical "high".

2.4 Internal Flag Setting Condition

TLE9252V has eight internal flags. Seven internal flags can be read out via NERR and RxD output pins. Detailed description of conditions when a flag is set and reset please see **Table 2**. See **Figure 19** for Diagnosis Flowchart

Table 2 Flag Setting Conditions

Flag Name	Set Condition	Reset Condition	NERR behavior when flag is set	RxD behavior when flag is set	Additional Information
V_{CC} undervoltage	$V_{CC} < V_{CC\_UV}$ AND t > t_{VCC_filter} in NM, ROM	$V_{CC} > V_{CC\_UV}$ for t > t_{VCC_filter} + $t_{VCC\_RECOVERY}$ in NM, ROM	NERR goes logical "low" in NM, ROM	Works according to mode definition	Transmitter blocked in NM.
Wake-up pattern via CAN bus (WUP)	Valid WUP detected in Low-power Modes	- Mode change from low-power mode to NM, ROM - Mode change to Sleep Mode due to an long-term undervoltage on V_{IO} OR V_{CC}	NERR is set to logical "low" in Go-to-Sleep Command and Stand-by Mode	RxD is set to logical "low" in Go-to-Sleep Command and Stand-by Mode	- INH "On" - Transition to Sleep Mode via Go-to-Sleep Command blocked by Host Command. Device stays in Go-to-Sleep Command.
Local Wake-up event (LWU)	LWU detected in Low-power Modes	- Mode change from low-power mode to NM, ROM - Mode change to Sleep Mode due to an long-term undervoltage on V_{IO} OR V_{CC}	NERR remains "high" in Go-to-Sleep Command and Stand-by Mode if no WUP has been detected	RxD is set to logical "low" in Go-to-Sleep Command and Stand-by Mode	INH "On", Transition to Sleep Mode via Go-to-Sleep Command blocked by Host Command. Device stays in Go-to-Sleep Command.
Over-temperature	T > T_{JSD} in Normal-operating Mode	- If T < T_{JSD} in Normal-operating Mode	NERR goes logical "low" in Normal-operating Mode.	Works according to mode definition	Transmitter is blocked in Normal-operating Mode
TxD dominant time-out	TxD "dominant" for t > t_{TXD_TO} in Normal-operating Mode	- TxD is "recessive" again in Normal-operating Mode - Mode change to Normal-operating Mode	NERR goes logical "low" in Normal-operating Mode. Latch of NERR $t_{NERR\_TXD\_TO\_LATCH}$ = 10µs... 20µs	Works according to mode definition	Transmitter is blocked in Normal-operating Mode.

Table 2 Flag Setting Conditions

Flag Name	Set Condition	Reset Condition	NERR behavior when flag is set	RxD behavior when flag is set	Additional Information
RxD recessive Clamping	RxD recessive when V_{diff} > 0,9V for longer than t_{RRC} in Normal-operating Mode	- RxD is "dominant" for t > t_{RRC} in Normal-operating Mode - Mode change to Normal-operating Mode	NERR is set to logical "low" in Normal-operating Mode.	Works according to mode definition	Transmitter is blocked in Normal-operating Mode
POR	Entering Stand-by Mode from Power On Reset	Mode change to Normal-operating Mode	NERR is set to logical "low" in Receive-only Mode	Works according to mode definition	- INH "On" - Transition to Sleep Mode via Go-to-Sleep Command is blocked.

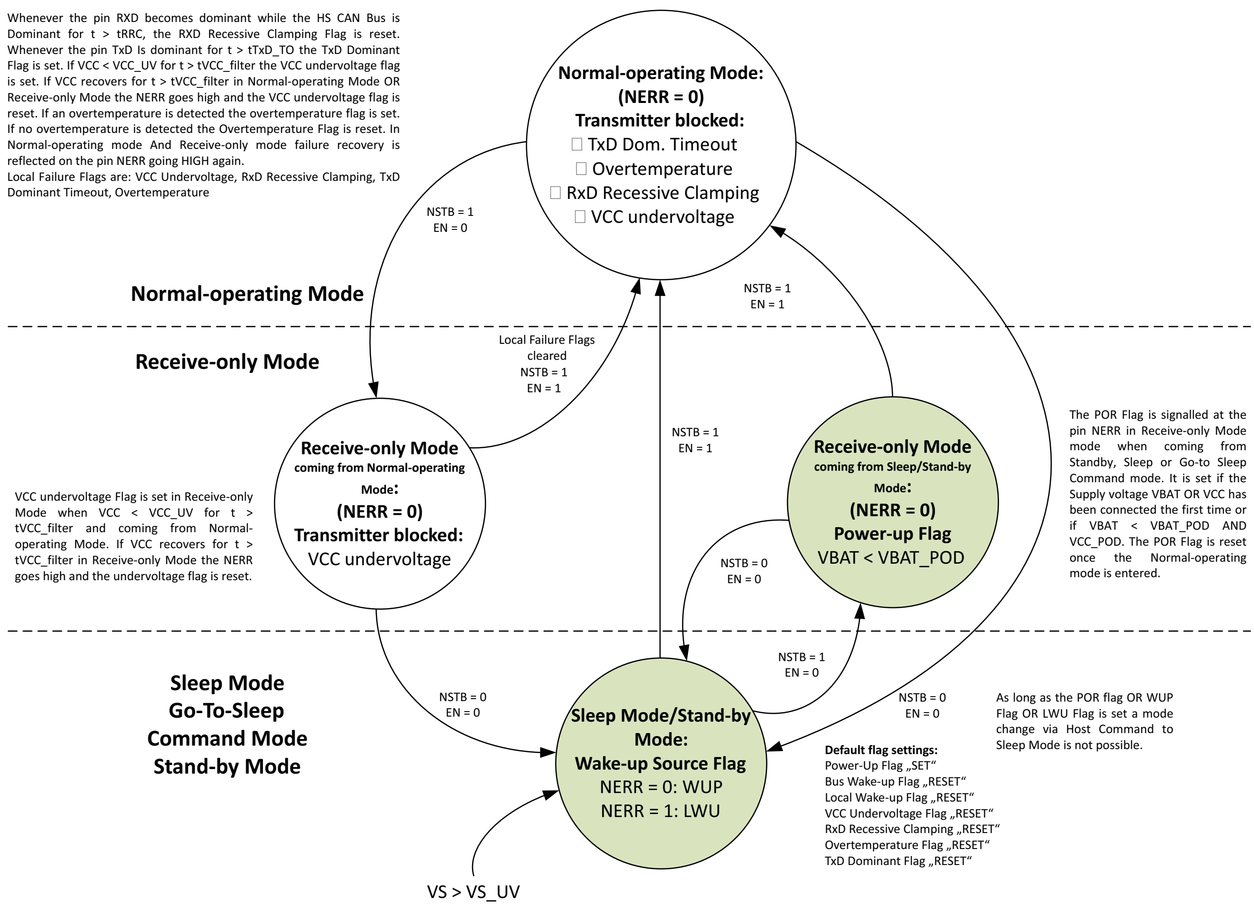


Figure 19 Diagnosis Flowchart

2.5 NERR behavior during mode changes

The HS CAN transceiver TLE9252V changes the mode of operation within the transition time period t_{Mode}. The transition time period t_{Mode} must be considered in developing software for the application. The following list describes the behavior of NERR output pin during mode change:

- If an undervoltage on V_{CC} has been detected in Normal-operating Mode, the NERR pin is set to logical "low". During mode change to Receive-only Mode the NERR pin stays logical "low". If the V_{CC} supply did not recover, the NERR stays logical "low" in Receive-only Mode (see **Figure 20**).
- If a RxD Recessive Clamping or TxD Dominant Time-out has been detected in Normal-operating Mode, the NERR pin is set to logical "low". During mode change to Receive-only Mode the NERR pin stays logical "low". After t_{Mode} when entering Receive-only Mode the NERR is set to logical "high" in Receive-only Mode.
- The diagnostics on NERR pin is updated after t_{Mode} has expired, when the mode transition is completed (see **Figure 20**).
- In Go-to-Sleep Command while t < t_{SLEEP} the NERR pin and RxD pin are set to logical "high" if no wake-up is pending.
- In Go-to-Sleep Command when coming from Stand-by Mode the NERR pin and RxD pin are set to logical "low" if a wake-up has been detected in Stand-by Mode.

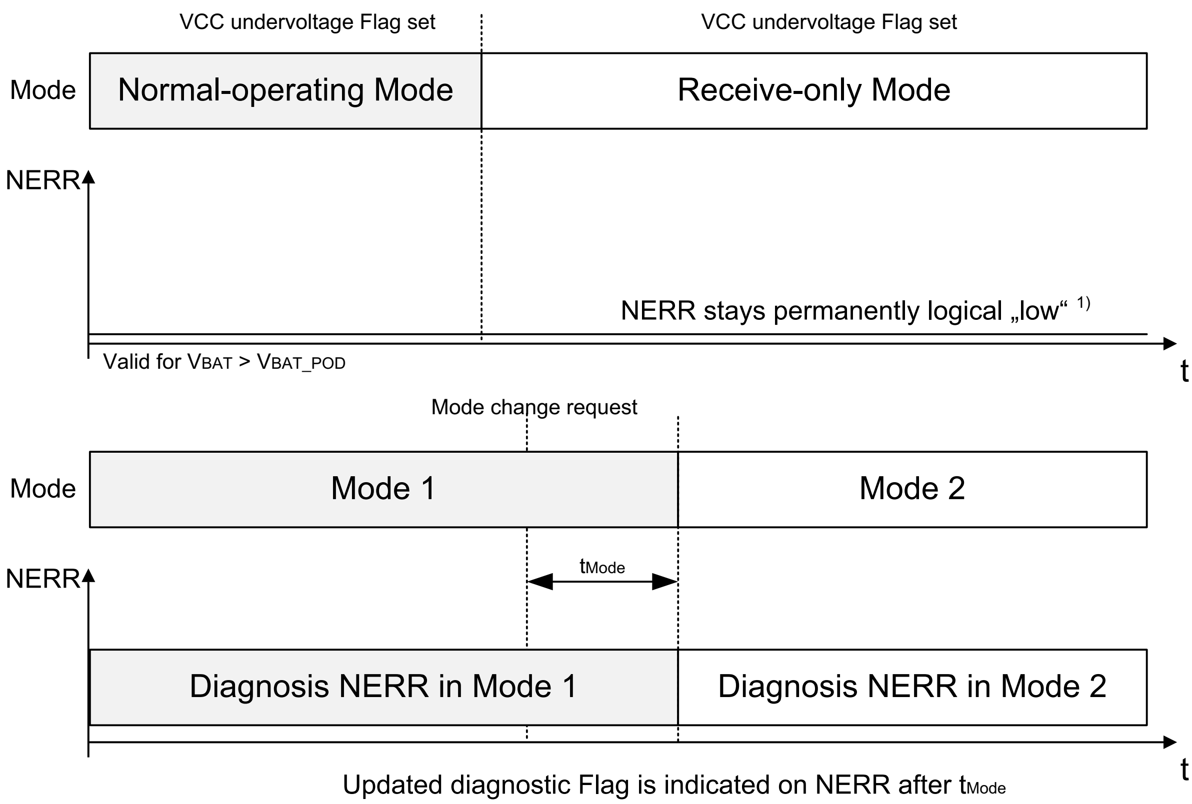


Figure 20 NERR Behavior during mode changes

Terms and Abbreviations

Table 3 Terms and Abbreviations

CMC	Common mode choke
EMC	Electromagnetic compatibility
EME	Electromagnetic emission
EMI	Electromagnetic interference
EOS	Electrical overstress
ESD	Electrostatic discharge
ESR	Equivalent Series Resistance
“high”	logical high
“low”	logical low
WUP	Wake-up pattern
NM	Normal-operating Mode
ROM	Receive-only Mode

3 Revision History

Revision	Date	Changes
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