Application Note
TLE9252V

Transceiver Control and Supply Aspects

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:

- CAN FD parameters according to ISO11898-2 (Edition 2016) (see **Chapter 3**)
- Protocol Changes Classical CAN and CAN Flexible Data Rate (see **Chapter 3.2**)
- Detailed Pin description (see **Chapter 4**)
- Power supply concepts (see **Chapter 5**)
- Current consumption aspects (see **Chapter 5.2**)
- Mode control hints (see **Chapter 6**)
- Bus wake-up pattern (WUP) and Local Wake-up (see **Chapter 7**)
- Fail safe behavior and features (see **Chapter 8**)
- TLE9252V Certificates Overview (see **Chapter 9**)

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

For Diagnostics via NERR pin please refer to TLE9252V Diagnostics Application Note

Intended audience

This document is intended for engineers who develop applications.

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.

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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 (+/-9 kV)
- Bus wake-up and Local wake-up (see **Chapter 7**)
- INH output pin to control external circuitry (see **Chapter 2**)
- Undervoltage detection on V_{BAT}, V_{CC} and V_{IO} (see **Chapter 5.4**)
- Very low current consumption in Stand-by and Sleep Mode (see **Chapter 5.2**)
- Autonomous Bus Biasing (see **Chapter 6.5**)
- Control input levels compatible with 3.3 V and 5 V devices
- Advanced diagnostics via NERR output pin

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 event the INH is enabled 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 (see **Chapter 5.2**). 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.

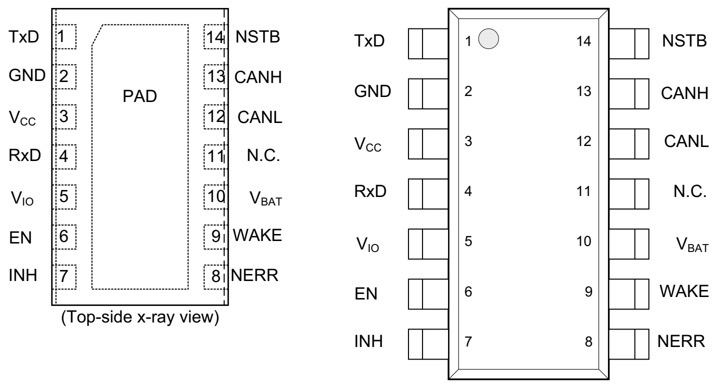


Figure 1 Pin Configuration of the TLE9252V

1.3 TLE9252Vxx Pin-out Compatibility

The TLE9252V is fully pin-out compatible to existing Infineon CAN transceivers TLE6251-3G and TLE6251-2G (see **Figure 3** and **Figure 2**). For Software adaption, behavioral differences of TLE6251-3G and TLE9252V are described in **Chapter 6.7**. As the TLE9252V has a N.C. with no internal connected function it can be directly placed on the footprint of TLE6251-2G with SPLIT pin (see **Figure 2**).

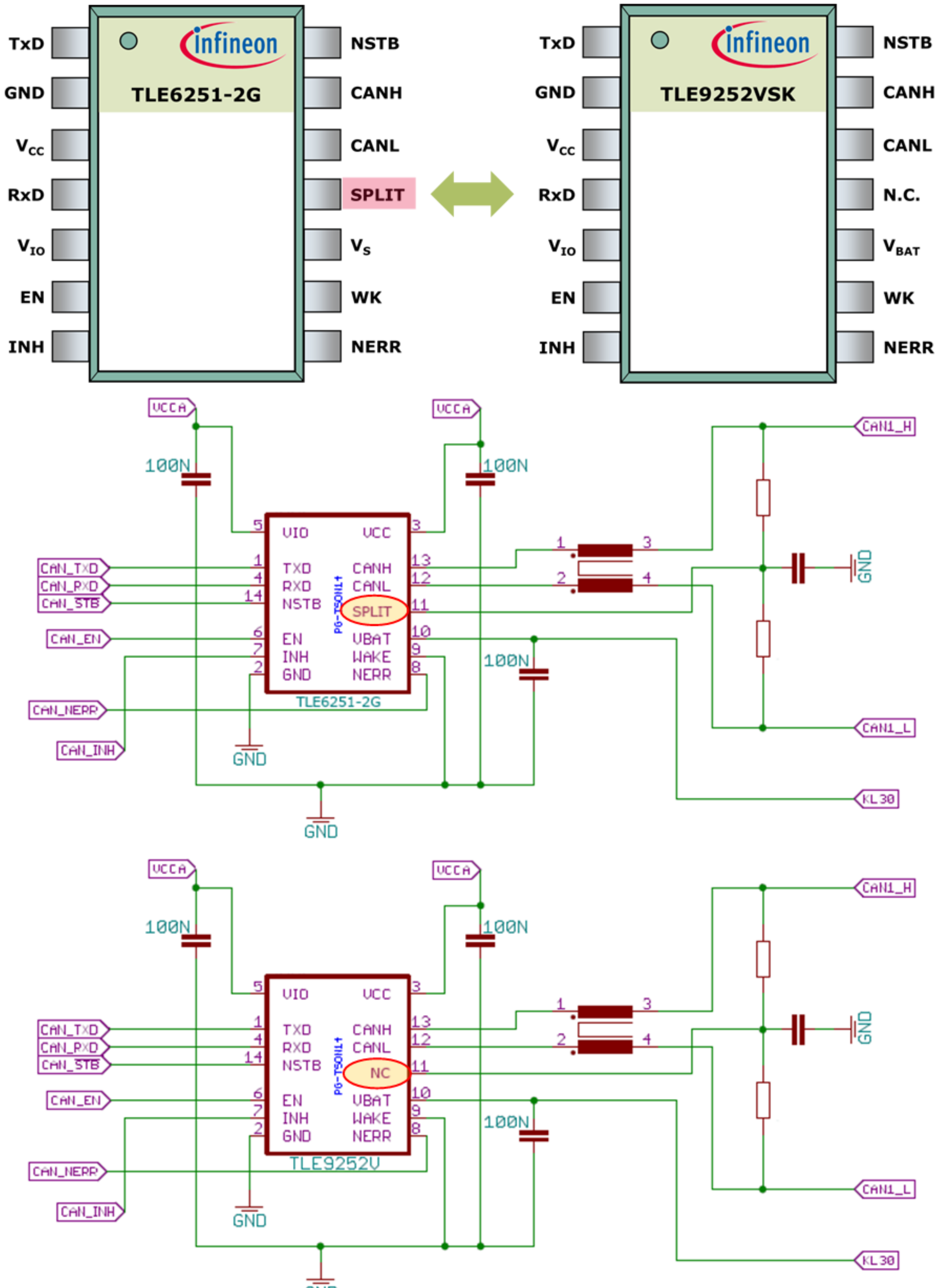


Figure 2 TLE9252V Pin-out Compatibility to TLE6251-2G

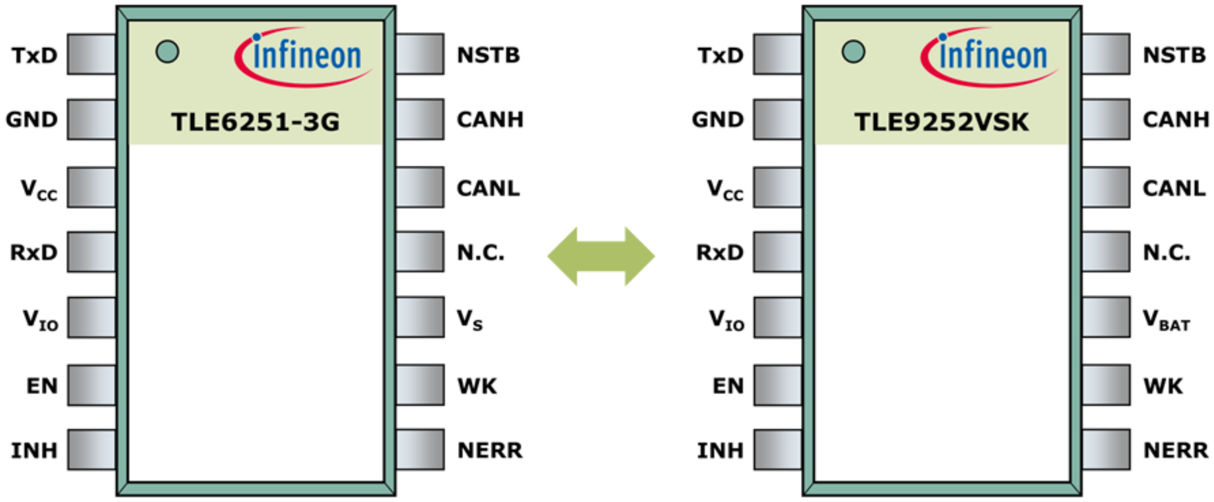


Figure 3 TLE9252V Pin-out Compatibility to TLE6251-3G

1.4 Infineon 5MBit/s CAN FD Transceiver Portfolio

Table 1 Feature Overview of Infineon 5Mbit/s CAN FD Transceiver

CAN FD Transceiver	Number of Pins	Modes					Fail-safe Features				Wake-up		NERR Diagnostics Output	SPI	INH output pin	Host Interface voltage range	Partial Networking
		Normal-operating Mode	Receive-only Mode	Stand-by Mode	Power-save Mode	Sleep Mode	TxD Dominant Time-out	Undervoltage detection	Over Temperature	Short Circuit Protection	Bus Wake-up	Local Wake-up					
TLE9250SJ/LE	8	✓	✓	–	✓	–	✓	✓	✓	✓	–	–	–	–	–	4.5 - 5.5V	–
TLE9250VSJ/VLE	8	✓	–	–	✓	–	✓	✓	✓	✓	–	–	–	–	–	3.0V - 5.5V	–
TLE9250XSJ/XLE	8	✓	✓	–	–	–	✓	✓	✓	✓	–	–	–	–	–	3.0V - 5.5V	–
TLE9251VSJ/VLE	8	✓	–	✓	–	–	✓	✓	✓	✓	✓	–	–	–	–	3.0V - 5.5V	–
TLE9251SJ/LE	8	✓	–	✓	–	–	✓	✓	✓	✓	✓	–	–	–	–	4.5 - 5.5V	–
TLE9252VSK/VLC	14	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	✓	–	✓	3.0V - 5.5V	–
TLE9255WSK/WLC	14	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓	–	✓	✓	3.0V - 5.5V	✓

2 Application Usage

The TLE9252V is the perfect choice for CAN nodes which are permanently V_{BAT} battery supplied (Clamp 30) and V_{IO} and V_{CC} supplies are switched off. A typical permanently supplied application consists of a voltage regulator and a microcontroller. The voltage regulator(s) of V_{CC} and V_{IO} are controlled by the INH pin of TLE9252V. Battery supply is connected to the voltage regulators and to TLE9252V.

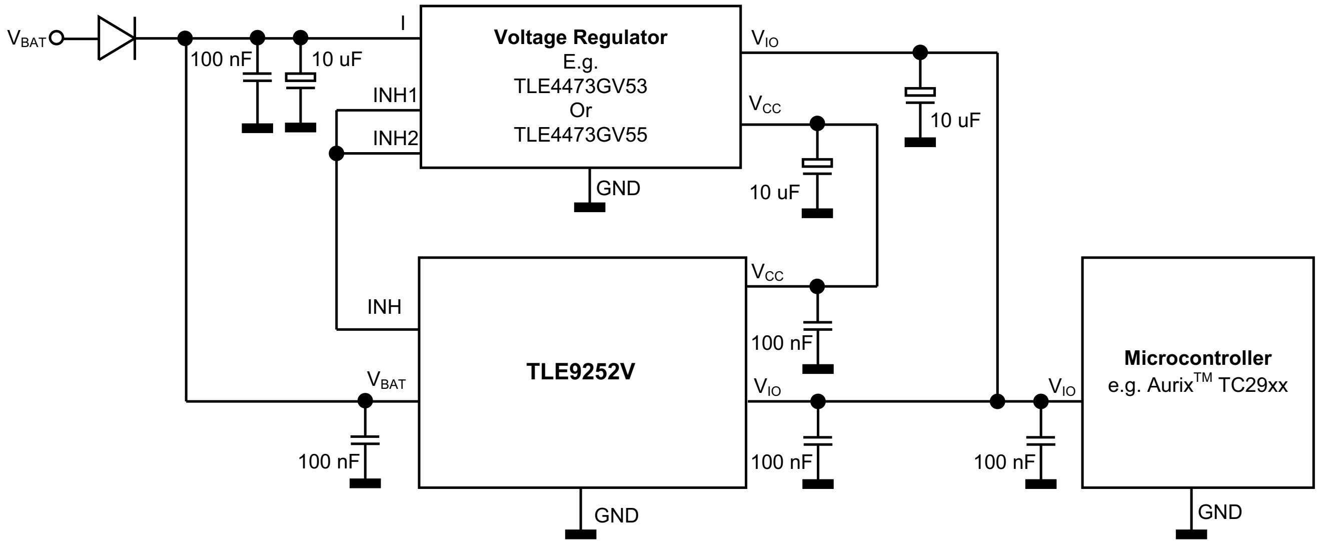


Figure 4 Example Application

For Low Power Management many in-vehicle networking architectures require the availability of CAN FD communication when ignition key is off. These applications require permanently battery supplied ECUs with ultra low current consumption. TLE9252V offers for Low Power Management reducing the quiescent current consumption of an ECU to about typ. 12µA, which saves battery current. With this low current consumption the transceiver is still keeping wake-up capability via the bus and via Local wake-up pin. This way the system can react on local events as well as on CAN messages, resulting in wake-up of the complete bus system. TLE9252V can be used also in other special applications (see **Chapter 5.3**)

3 CAN FD

CAN FD (Flexible Data Rate) is the advanced version of classical CAN.

CAN FD saves transmission time compared to classical CAN:

- increased data transmission rate
- increased payload per message

CAN FD includes additional timing parameters.

Table 2 Classical CAN vs. CAN FD

	Maximum Data transmission rate [Mbit/s]	Maximum payload message length [byte]
Classical CAN	1	8
CAN FD	5	64

CAN FD uses the same physical layer as classical CAN does. During the arbitration phase and checksum the data transmission rate is identical to classical CAN (1 Mbit/s). As soon as one node in the CAN FD network starts transmitting the payload, the data rate is increased up to 5 Mbit/s. The increased baud rate is possible, because only one node transmits during the data transmission phase. All other nodes listen to the data on the CAN bus. In order to ensure reliable data transmission, a CAN FD network requires CAN FD transceiver which are fully compliant to the ISO 11898-2: 2016 specification.

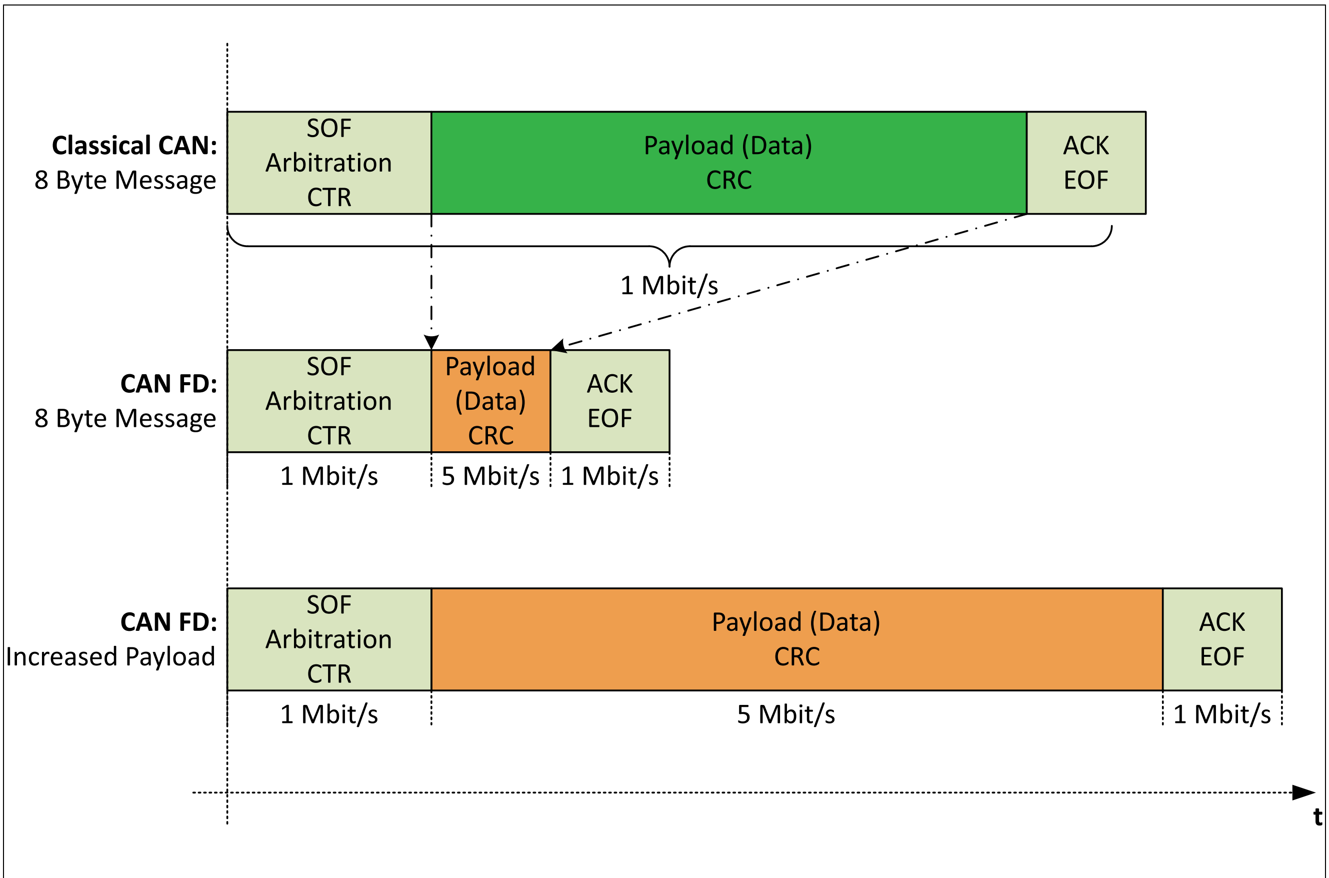


Figure 5 Classical CAN Data Rate and CAN FD Data Rate 5Mbit/s

The CAN bus physical layer can have the following states (see **Figure 6**):

- dominant:
  - TxD pin set to "low" generates dominant state
  - voltage at CANH changes towards V_{CC}
  - voltage at CANL changes towards GND
- recessive:
  CANH and CANL are biased to $V_{CC}/2$

See **Table 3** for voltage levels specified for dominant and recessive state.

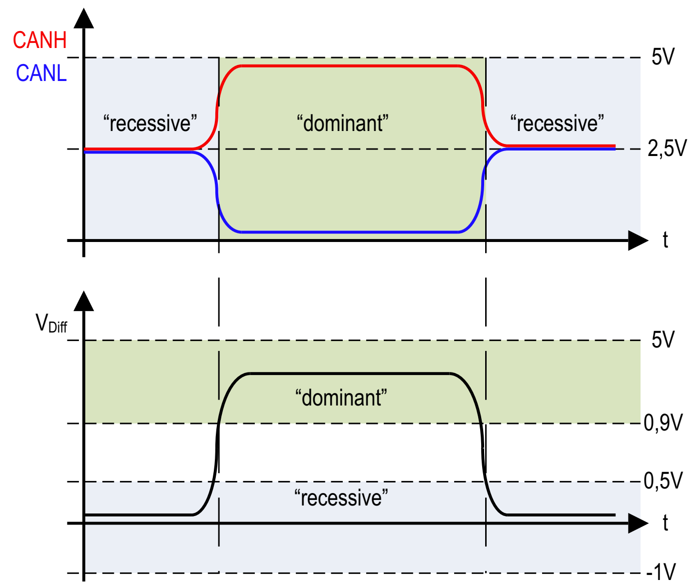


Figure 6 Voltage Levels according to ISO 11898-2

Table 3 Voltage Levels according to ISO 11898-2 (Ed. 2016)

Parameter	Symbol	Values			Unit	Note or Test Condition
		Min.	Typ.	Max.		
Recessive State						
Output Bus Voltage	$V_{CANL,H}$	2.0	2.5	3.0	V	No load
Differential Output Bus Voltage	$V_{Diff\_R\_NM}$	-500	–	50	mV	No load
Differential Input Bus Voltage	$V_{Diff\_R\_Range}$	-3.0	–	0.5	V	–
Dominant State						
Output Bus Voltage	V_{CANH}	2.75	3.5	4.5	V	$50\ \Omega < R_L < 65\ \Omega$
	V_{CANL}	0.5	1.5	2.25	V	$50\ \Omega < R_L < 65\ \Omega$
Differential Output Bus Voltage	$V_{Diff\_D\_NM}$	1.5	2.0	3.0	V	$50\ \Omega < R_L < 65\ \Omega$
Differential Input Voltage	$V_{Diff\_D\_Range}$	0.9	–	8.0	V	–

ISO 11898-2 describes the CAN physical layer. The CAN transceiver TLE9252V fulfills all parameters defined in ISO 11898-2. This document describes CAN applications with the TLE9252V. It provides application hints and recommendations for the design of CAN electronic control units (ECUs) using the CAN transceiver TLE9252V from Infineon.

3.1 TLE9252V CAN FD Parameters

The TLE9252V from Infineon is the perfect match for CAN FD networks. TLE9252V exceeds the CAN FD parameters according to ISO 11898-2: 2016 for 2Mbit/s and 5Mbit/s in order to enable smooth and safe usage within applications. **Figure 7** shows an example calculation of network propagation delays applying CAN FD 2Mbit/s parameters according to ISO11898-2: 2016 specification listed in **Table 4**.

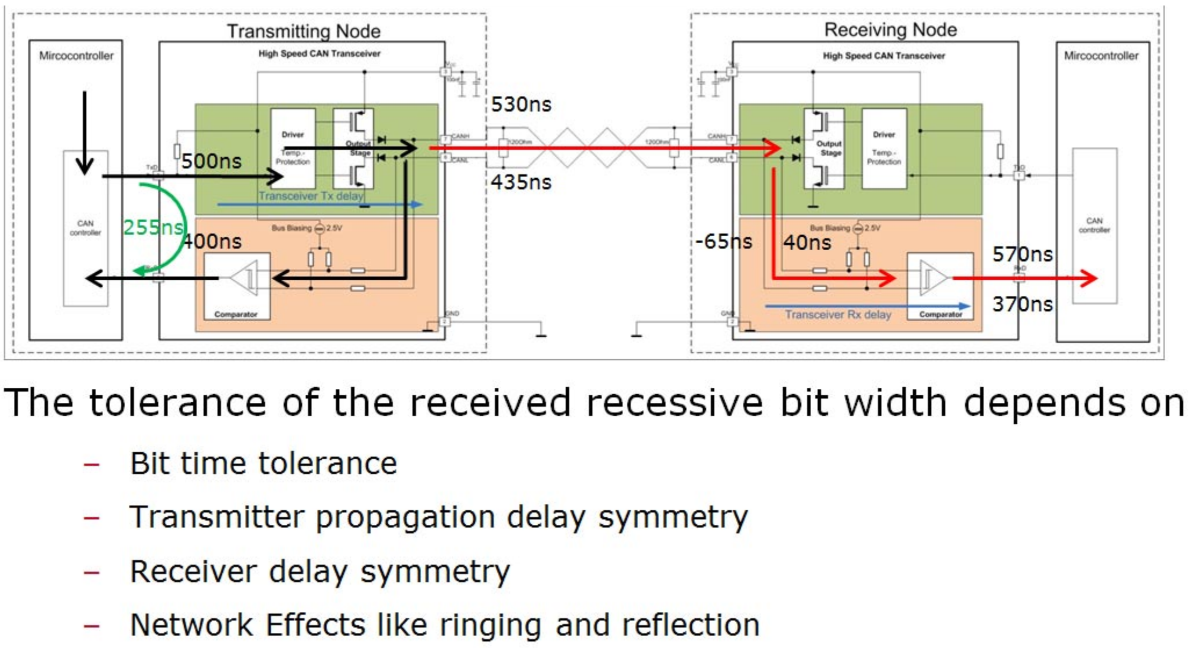


Figure 7 Propagation Delay Effects in CAN Networks: Example with 2Mbit/s

Table 4 CAN FD Specification of TLE9252V

Specification	**CAN FD Specification ISO 11898-2 (2016)**		
Parameter	min	max	Unit
Received recessive bit width on transmitting node (2Mbit/s)	400	550	ns
Transmitter delay symmetry (2Mbit/s)	435	530	ns
Receiver delay symmetry (2Mbit/s)	-65	+40	ns
Received recessive bit width on receiving node (2Mbit/s)	370	570	ns
Received recessive bit width on transmitting node (5Mbit/s)	120	220	ns
Transmitter delay symmetry (5Mbit/s)	155	210	ns
Receiver delay symmetry (5Mbit/s)	-45	+15	ns
Received recessive bit width on receiving node (5Mbit/s)	110	225	ns

TLE9252V fulfills all timing parameters for CAN Flexible Data Rate 2Mbit/s and 5Mbit/s, which adds additional safety margin for network effects like ringing effects and network propagation delay.

3.2 Protocol Changes with CAN FD

Using CAN Flexible Data Rate also requires the usage of the ISO Frame Format CAN Flexible Data Rate Protocol for a save application. The Protocol Changes from Classical CAN Frame to CAN FD Frame Format implies:

- Increased payload of up to 64bytes per frame
- Increased data rate up to 5Mbit/s
- Extended Identifier up to 29 bits
- Extended Cyclic Redundancy Check (CRC) of up to 21 bits
- New Control Field bits (Flexible Data Rate Frame Indicator Bit, Bit Rate Switch, Remote Request Substitution Bit, Error State Indicator Bit)

This has significant impact on the wake-up requirements of CAN transceivers. A more detailed description and explanation of the Wake-Up Pattern (WUP) is included in **Chapter 7.1**. Classical CAN filter activity has been defined as 0.5µs < t_{Filter} < 5µs. Assuming the worst case of 6µs two Classical CAN Frames are needed to guarantee a wake-up as visualized in **Figure 8**.

In a CAN FD Frame there are no guaranteed three dominant bits (Red frame) any more, as the new FDF- and BRS-Bit are recessive. For reliable and robust bus wake-up within CAN FD networks, european OEMs request a maximum t_{Filter} < 1.8µs timing to ensure a wake-up with every CAN FD Frame.

A minimum of t_{Filter} > 0.5µs offers high robustness against transients and noise on the HS CAN Bus which is required by NAFTA region OEMs.

Therefore Infineon's TLE9252V has the improved wake-up filter time specified as 0.5µs < t_{Filter} < 1.8µs, enabling high robustness against transients and ensuring a bus wake-up with every possible Frame Format on the HS CAN Bus. TLE9252V fulfills worldwide bus wake-up t_{Filter} timing requirements.

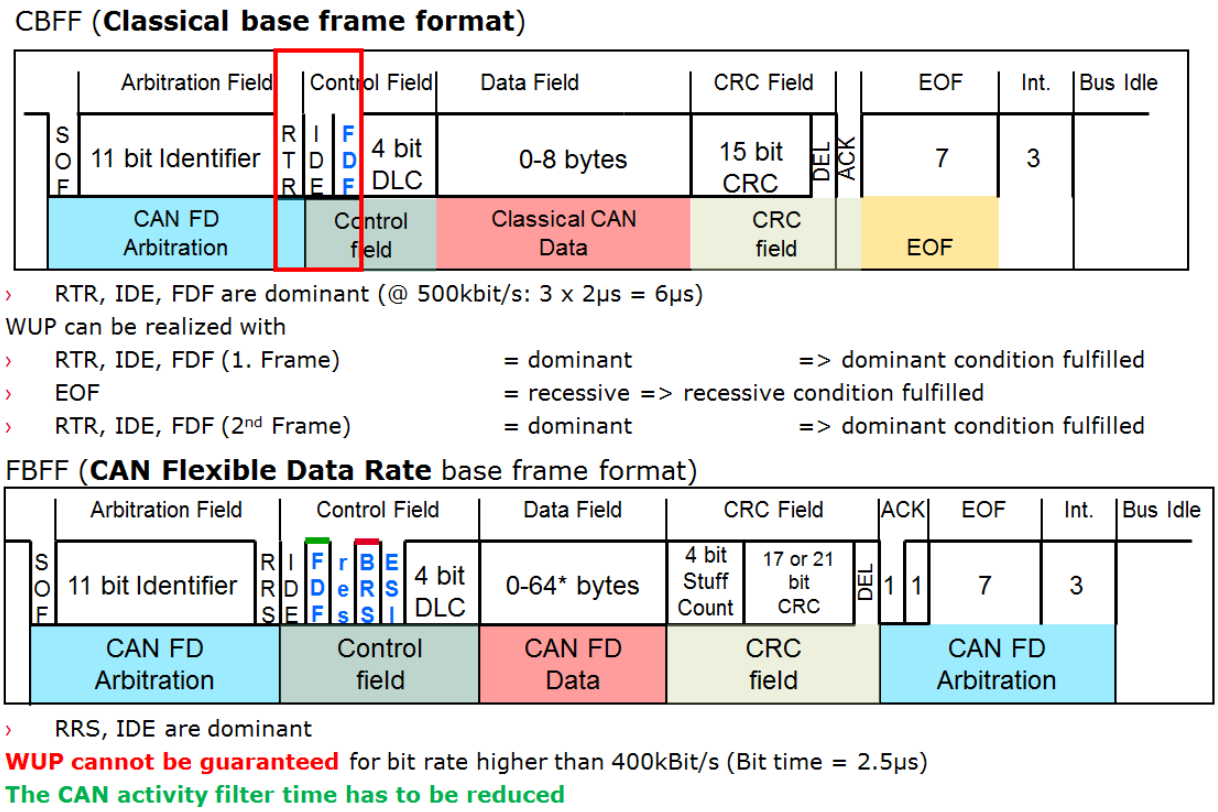


Figure 8 Protocol Changes Classical CAN Frame to CAN FD Frame

4 Pin Description

This chapter describes the function of each pin of TLE9252V in more detail.

4.1 V_{BAT} Pin

The V_{BAT} pin is needed for permanently supplied applications (Clamp 30). V_{BAT} pin is connected usually via a reverse protection diode to the battery supply voltage. The internal logic (state machine) is supplied by V_{BAT}. By default after an undervoltage on V_{BAT} or after first power-up the device enters Stand-by mode.

4.2 V_{IO} Pin

The V_{IO} pin is needed for the operation with a microcontroller that is supplied by $V_{IO} < V_{CC}$, to match the voltage level between microcontroller and transceiver. It can also be used to decouple microcontroller and transmitter supply and improve the EMC performance. As long as V_{IO} > 3.0 V the logic input pins of the transceiver are unblocked and support mode changes. Below V_{IO} < 3.0 V the input pins are blocked and the device enters Stand-by Mode due to the internal pull-down resistors on NSTB and EN input pin. The V_{IO} supply pin must be connected to the power supply of the microcontroller. Due to the V_{IO} pin feature, the TLE9252V can work with various microcontroller supplies. To enter Normal-operating mode V_{IO} ≥ 3.0 V is required.

4.3 V_{CC} Pin

The V_{CC} pin supplies the transmitter output stage and the internal logic.

Table 5 Transmitter state depending on V_{CC}

V_{CC}	Transmitter state	Note
$V_{CC} < V_{CC\_UV}$	disabled	4.0 V < V_{CC_UV} < 4.5 V
$V_{CC\_UV} < V_{CC}$ < 4.5 V	enabled; parameters may be outside the specified range	–
4.5 V < V_{CC} < 5.5 V	enabled	–
V_{CC} > 6 V	damage of TLE9252V possible	–

4.4 External Circuitry for V_{BAT}, V_{CC} and V_{IO} pin

In order to reduce EME and improve the stability of supply voltage levels on V_{BAT}, V_{CC} and V_{IO} pins, it is higly recommended to place capacitors on the PCB. During sending a dominant bit to the HS CAN bus, current consumption of TLE9252V is higher than during sending a recessive bit. Data transmission changes the load profile on V_{CC} which may reduce the stability of V_{CC}. If several CAN transceivers are connected in parallel, and supplied by the same V_{CC} and/or V_{IO} power supply, the impact on the stability of V_{CC} is even stronger. It is highly recommended to place a 100 nF capacitor as close as possible to V_{CC} and V_{IO} pin. It is recommended to place a 1µF and 100nF capacitor close to V_{BAT} supply pin. Ceramic capacitors are recommended for low ESR.

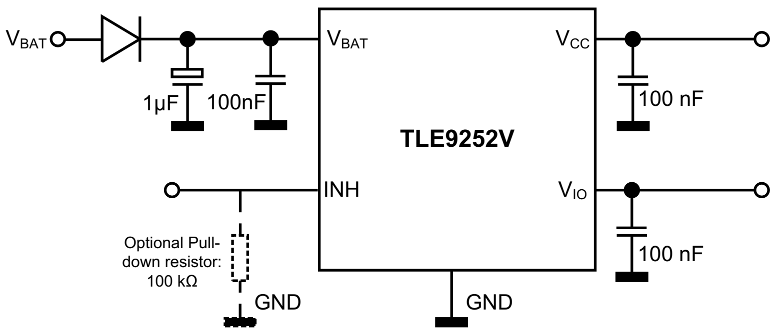


Figure 9 External Circuitry Example of TLE9252V

4.5 GND Pin

The GND pin must be connected as close as possible to module ground in order to reduce ground shift. It is not recommended to place filter elements or an additional resistor between GND pin and module ground. GND must be the same for transceiver, microcontroller and HS CAN bus system.

4.6 RxD Pin

The RxD is an output pin. The data stream received from the HS CAN bus is displayed on the RxD output pin in Normal-operating mode and Receive-only mode. In Sleep Mode and Standby Mode by default the RxD pin is "high". If a bus wake-up is detected in Sleep Mode or Stand-by mode, then the RxD pin goes "low" in order to indicate a wake-up event to the microcontroller. Do not use a series resistor within the RxD line between transceiver and microcontroller. A series resistor causes additional delay, which degrades the performance of the transceiver, especially in high data rate applications using CAN FD.

4.7 TxD Pin

TxD is an input pin and receives the data stream from the microcontroller. If in Normal-operating mode $V_{IO} > V_{IO\_UV}$, the data is transmitted to the HS CAN bus. In all other modes the TxD input pin is blocked. A "low" signal causes a dominant state on the bus and a "high" signal causes a recessive state on the bus. The "high" signal must be adapted to the voltage on the V_{IO} pin. This means the "high" level must not exceed V_{IO} voltage. The TxD input pin has an integrated pull-up current source to V_{IO}. If TxD is permanently "low", for example due to a short circuit to GND, then the TxD time-out feature will block the signal on the TxD input pin (see **Chapter 8.2**). Do not use a series resistor within the TxD line between transceiver and microcontroller. A series resistor may add additional delay, which has negative impact especially on CAN FD applications.

4.8 EN and NSTB Pin

EN pin and NSTB pin set the mode of operation of TLE9252V and are usually connected to output ports of a microcontroller. If the mode pins are not connected, then the device enters Stand-by Mode, due to the internal pull-down current sources to GND on EN and NSTB. **Table 6** shows mode changes via the EN and NSTB pins.

Table 6 Mode Selection via EN and NSTB

Mode of Operation	NSTB	EN	Transmitter	Receiver	Low-power Receiver
Normal-operating Mode	"high"	"high"	enabled	enabled	disabled
Receive-Only Mode	"high"	"low"	disabled	enabled	disabled
Stand-by Mode	"low"	"low"	disabled	disabled	enabled
Go-to-Sleep Command	"low"	"high"	disabled	disabled	enabled
Sleep Mode	"low"	"low"	disabled	disabled	enabled

Sleep Mode and Stand-by Mode are the low-power mode of TLE9252V where transmitter and receiver are disable and current consumption is minimized. In Sleep Mode the INH pin is disabled and connected voltage regulator is switched off in order to reduce the current consumption of the ECU to its minimum.

There are three possibilities to deactivate the transmitter of TLE9252V in the following ways:

- set EN pin to "low"
- set NSTB pin to "low"
- Disconnect V_{CC} supply ($V_{CC} < V_{CC\_UV}$)

This can be used to implement different fail safe paths (see **Chapter 4.8.1**).

4.8.1 Secondary Safety Path Options

Because of the two mode pin of TLE9252V (EN, NSTB), safety relevant applications can implement separate input signal paths from:

- the host microcontroller (for example **Aurix™**)
- a safety system supply (for example TLF35584) which monitors the host microcontroller

In case the host microcontroller is damaged or running out of control, the safety watchdog or safety system supply has the possibility to deactivate the transmitter of the transceiver. This feature can be used in order to prevent the host microcontroller from sending corrupted messages to the CAN bus and to block the communication on the CAN bus. A possible scenario is for example a babbling idiot.

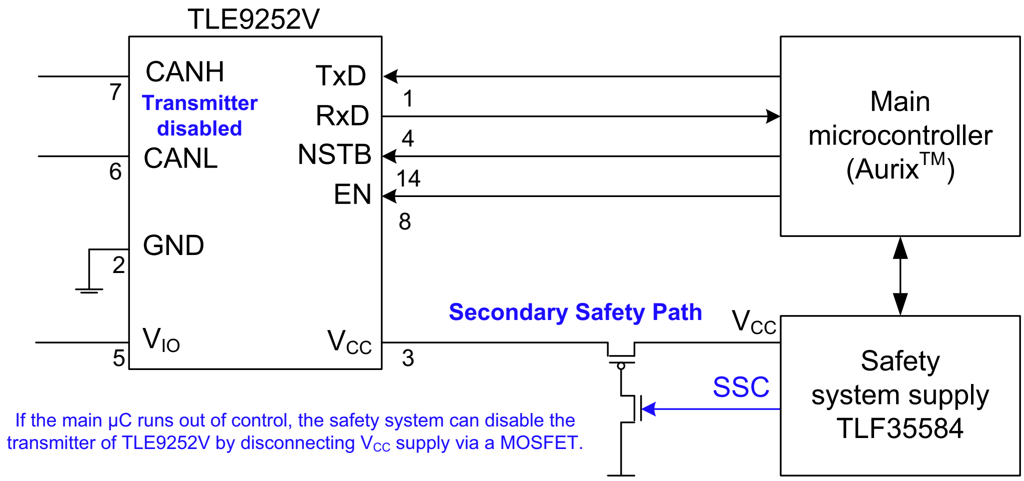


Figure 10 Example 1: Application with Aurix™ and safety system supply TLF35584

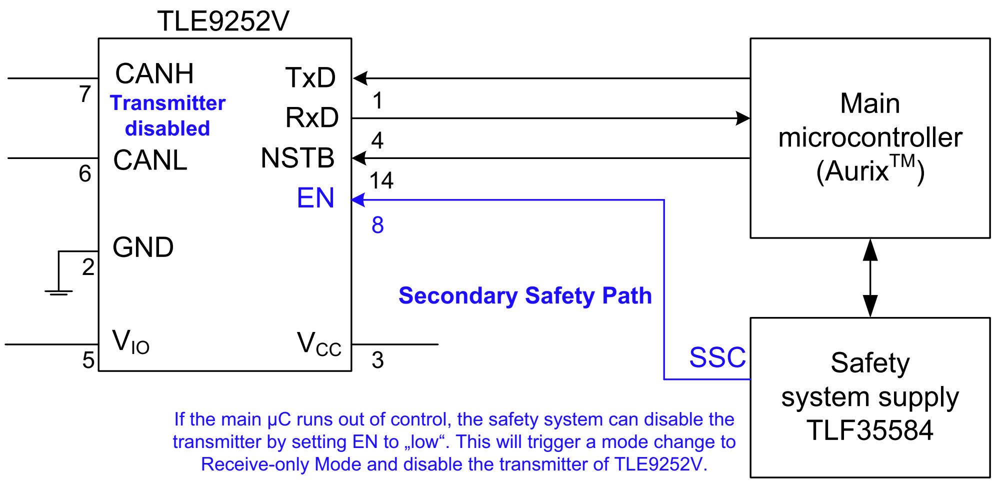


Figure 11 Example 2: Application with Aurix™ and safety system supply TLF35584

4.9 CANH and CANL Pins

CANH, CANL are the CAN bus input and output pins. The TLE9252V is connected to the bus via pin CANH and CANL. Both transmitter output stage and the receiver are connected to CANH and CANL. Data on the TxD pin is:

- transmitted to CANH and CANL
- simultaneously received by the receiver input and signalled on the RxD output pin.

For achieving optimum EME (Electromagnetic Emission) performance, transitions from dominant to recessive and from recessive to dominant are performed as smooth as possible also at high data rate. Output levels of CANH and CANL in recessive and dominant state are described in **Table 3**. Due to the excellent ESD performance on CANH and CANL no external ESD components are necessary to fulfill OEM requirements.

4.10 INH Pin

The INH pin can be used to control one or more external voltage regulator for V_{CC} and V_{IO} supply. The pin INH provides a battery related open drain output. If TLE9252V enters Sleep Mode INH is High-Z. Common voltage regulators do have a pull-down resistor on the Inhibit input pin, which results in a “low” signal and switches off the voltage regulator. In case the voltage regulator does not have an internal pull-down resistor, an external pull-down at the INH pin of TLE9252V can be placed (see **Figure 9**). In all other modes the pin INH is actively pulled to battery voltage V_{BAT}. The maximum current capability of INH pin is specified as 5mA.

Figure 9 shows the voltage drop on INH pin depending on the current for T_J = 25°C and V_{BAT} = 12V. Worst case voltage drop for 5mA current (V_{BAT} = 40V, T_J = 150°C) is 2.5V. R_{INH_ON} ~ 400Ω.

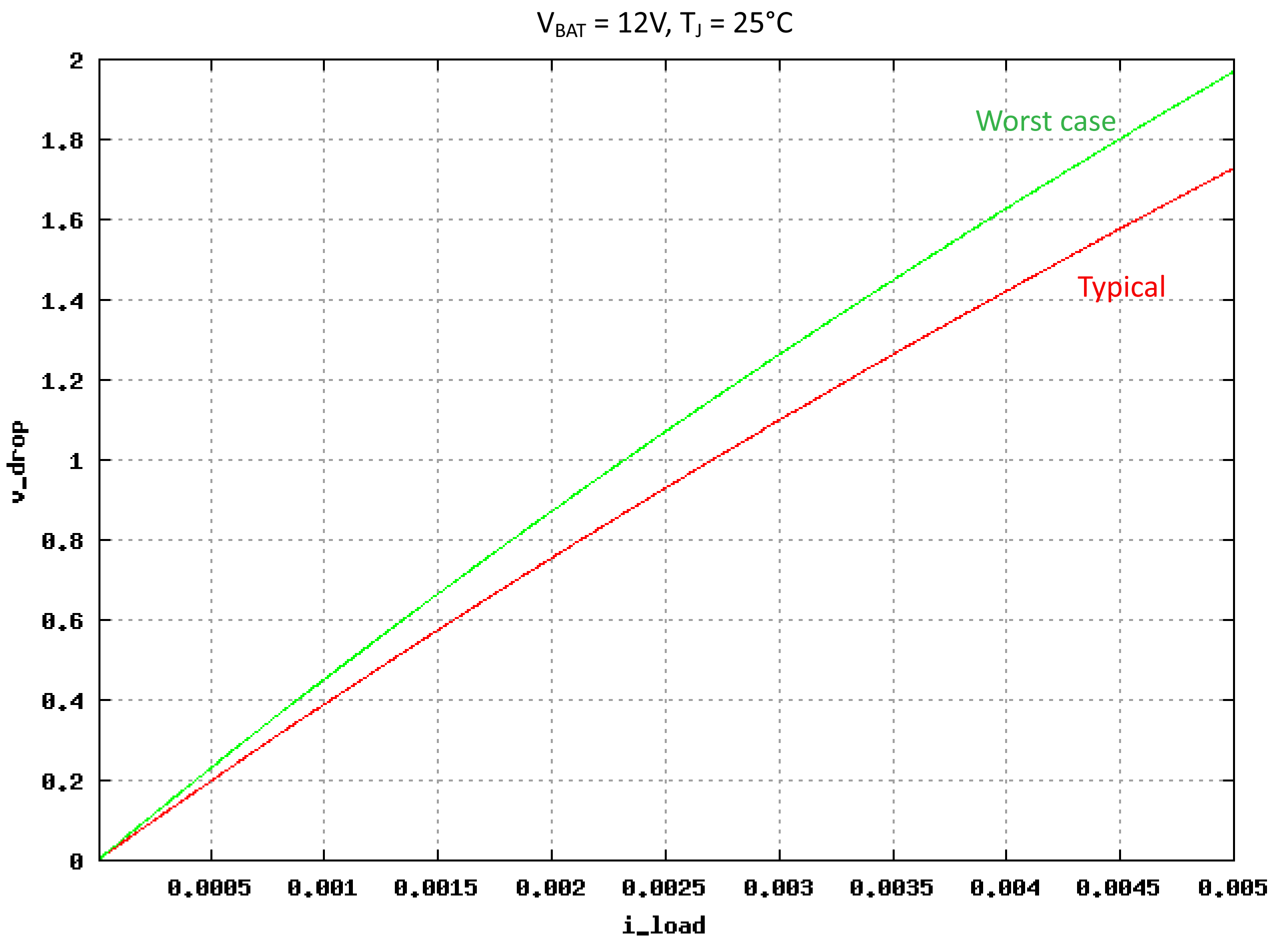


Figure 12 **Voltage drop characteristics on INH pin depending on current**

4.11 WAKE Pin

The WAKE input pin can be used to detect a local wake-up event by e.g. a switch to the transceiver. A rising and a falling edge can be applied to trigger a local wake-up. This concept allows using a low-side switch as well as a high-side switch to V_{BAT}. Typically, a low-side switch is used at the pin WAKE as shown in **Figure 13**. R_{VBAT_WAKE} (recommended 20kΩ) is for protection and limits the current in case the ECU has lost its ground connection. The minimum required series resistor is defined by the maximum allowed current at pin WAKE of 15 mA. The resistor is required to determine the current will not exceed this level. The minimum required series resistor R_S can be calculated by: $R_{S,min} = V_{BAT,max} / I_{WAKE,max}$. Typically a series resistor of 3.3kΩ

Absolute maximum rating of V_{BAT} is 40V DC, the series resistor should have a value of 3.3kΩ. The resistor R_{VBAT_WAKE} is needed to turn the bias to its default state after the external switch has been released. An upper limit for the resistor value is the result. With a low-side switch the resistor R_{VBAT_WAKE} together with the series resistor R_S must pull the pin WAKE above the switching threshold $V_{th(Wake)}$ of the pin WAKE. The equation for determining the upper limit for R_{VBAT_WAKE} is: $(R_{VBAT\_WAKE} + R_S) * I_{Pull,max} < V_{BAT\_min} - V_{WAKE\_TH,max}$ resulting in $(R_{VBAT\_WAKE} + R_S) * I_{Pull,max} < 0.35 * V_{BAT\_min}$. With the maximum pull-down (pull-up) current of 20uA and the maximum threshold of V_{WAKE_TH}, the theoretical upper limit for R_{VBAT_WAKE} calculates to about 92 kOhm. A typical value is 20 kOhm.

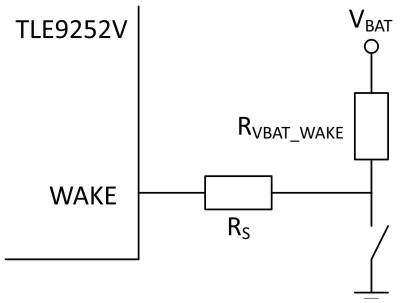


Figure 13 WAKE input pin circuitry

If the WAKE input pin is not used, it is recommended to connect WAKE directly to V_{BAT}. Also in order to prevent false local wake-up events during battery ramp up a pull-up resistor should be placed (see **Chapter 7.4**).

4.12 N.C. Pin

The N.C. pin has no function and is not connected to the internal TLE9252V chip. It must be left open or should not be connected to any other potential than GND.

4.13 NERR pin

The NERR pin is the diagnostic output of TLE9252V. Depending on the mode of operation the NERR pin allows to evaluate the transceivers status, pending wake-ups and failure detection. For detailed information please refer to “Application Note: TLE9252V Diagnostics via NERR”.

5 Transceiver Supply Aspects

This chapter includes power supply concepts and current consumption aspects of TLE9252V. The integrated Dual Supply Solution of TLE9252V offers the possibility to supply the device via V_{BAT} and V_{CC} pin. The benefit of this solution is during battery supply cranking. The TLE9252V remains fully functional while V_{CC} is stable. In order to stabilize the input voltage of the voltage regulator during battery voltage cranking, a buck-boost-converter can be used. The TLE9252V can also be used in 5V applications with leaving V_{BAT} pin n.c. and only supplied by V_{CC} pin. For further information regarding the Dual Power Supply Concept please see **Chapter 5.3**.

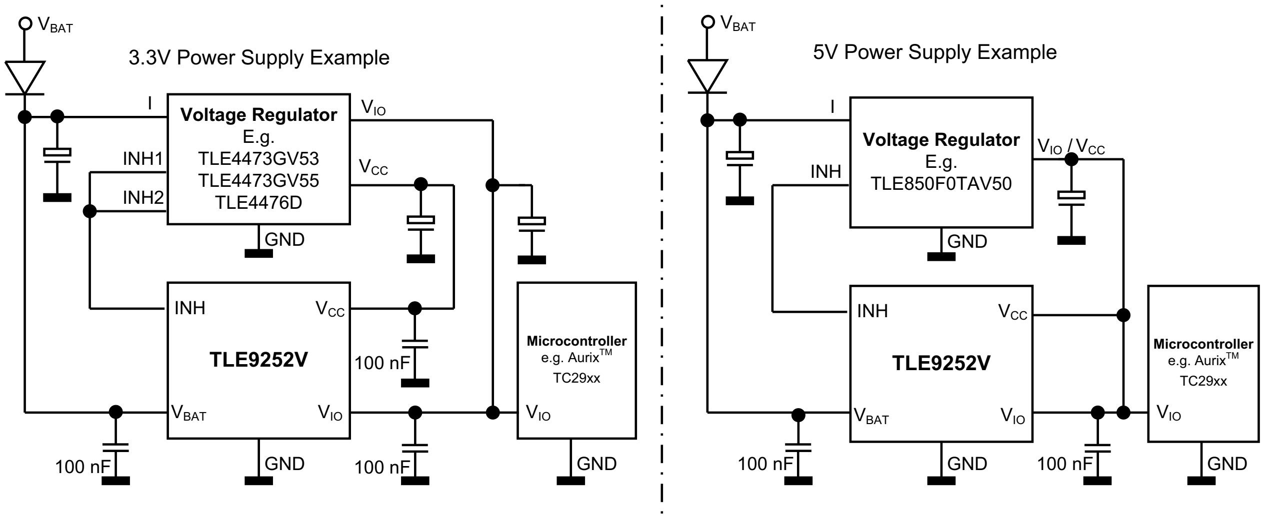


Figure 14 3.3V and 5V Supply Concept Examples

5.1 Voltage Regulator

It is recommended to use one of the following Infineon low drop output (LDO) voltage regulators, depending on the V_{CC} and V_{IO} power supply concept and feature requirements:

- 5 V V_{IO} and V_{CC} power supply: **TLF80511TC** (400mA), **TLS850F0TA V50** (500mA), **TLS850F0TA V50** (500mA),
- 3.3 V and 5 V dual voltage power supply: **TLE4473GV53** (300mA + 180mA), **TLE4476D** (350mA + 430mA)
- Dual 5V voltage power supply: **TLE4473GV55** (190mA + 300mA)

Please refer to **Infineon Linear Voltage Regulators** for the Infineon voltage regulator portfolio and data sheets.

5.2 Current Consumption Aspects

For TLE9252V special care was taken of low system power consumption since this is a key feature of battery supplied CAN transceivers. TLE9252V provides a minimized current consumption in Sleep Mode of max. 26µA.

Even with the extremely low system power consumption the TLE9252V provides full wake-up capability via the HS CAN bus or Local Wake-up pin, maintaining high immunity against electromagnetic disturbance.

Table 7 Maximum Current Consumption in Low-power Modes

Mode of Operation	Current Consumption I_{BAT} @ V_{BAT} = 13.5V						Unit
	@25°C		@105°C		@150°C		
	typ.	max.	typ.	max.	typ.	max	
Sleep Mode	11	17	13	20	15	26	µA
Standby Mode	21	24	23	27	28	50	µA

5.3 Dual Power Supply Solution

The integrated Dual Power Supply Concept of TLE9252V offers the possibility to supply the device with V_{BAT} OR/AND V_{CC} pin. There are two benefits of this solution in the application:

- During battery supply cranking, the TLE9252V remains fully functional when V_{CC} is stable
- TLE9252V can be used in applications with leaving V_{BAT} pin n.c. and only supplied by V_{CC} pin (see **Figure 15**)

During ignition of the car, the battery supply may drop down to 3V, which usually causes a power on reset of the ECU. In order to avoid a reset of the ECU, applications use a pre regulator (e.g. buck boost converter) in order to stabilize the input voltage of the voltage regulator down to a battery voltage of V_{BAT} = 3V. This will stabilize the V_{CC} and V_{IO} voltage and the microcontroller is running stable during battery voltage cranking. Common 14-pin CAN transceivers are only supplied by V_{BAT}, which would lead to a power on reset of the transceiver and would block the communication during battery cranking. Using Infineon integrated Dual Power Supply Solution the TLE9252V remains fully functional during battery supply cranking, if V_{CC} remains stable (V_{CC} > 4.5V) (see **Figure 16**). The Power-down threshold on V_{CC} supply is in the range 2.6V < V_{CC_POD} < 4.0V. The benefit for the network is, the communication will not be disturbed and no restart of the whole network communication has to be performed. V_{CC} voltage can also be stabilized with a larger output capacitor at the output of the voltage regulator or by using a Buck-Boost-Converter.

TLE9252VSK internal state machine is supplied by **V_{BAT} OR V_{CC}**

Benefit:
- ✓ During battery supply cranking the TLE9252VSK state machine does not perform a RESET => **No disruption of communication** during V_{BAT} cranking
- ✓ TLE9252VSK can be used for **5V application**

- ✓ V_{CC} supply stabilized by Buck Boost Converter down to V_{BAT} > 3V.
- ✓ TLE9252VSK works continuously if V_{BAT} drops

- ✓ V_{CC} supply can be used in 5V application by just connecting V_{CC} supply

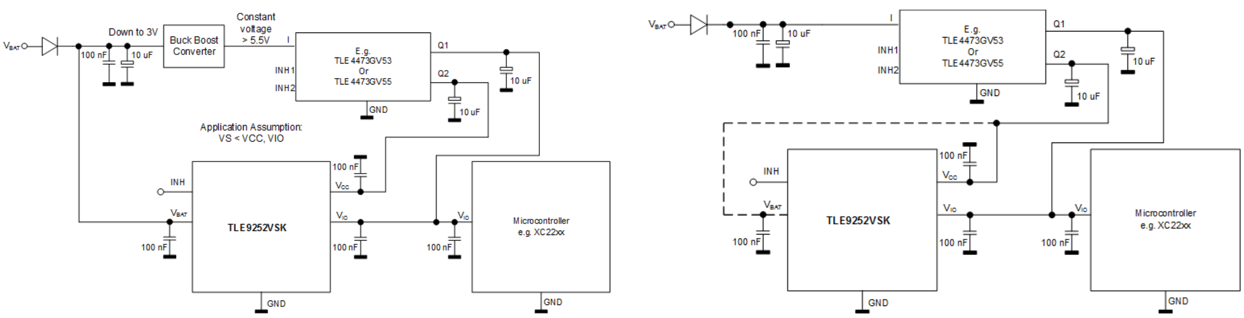


Figure 15 Benefits of Dual Power Supply Concept

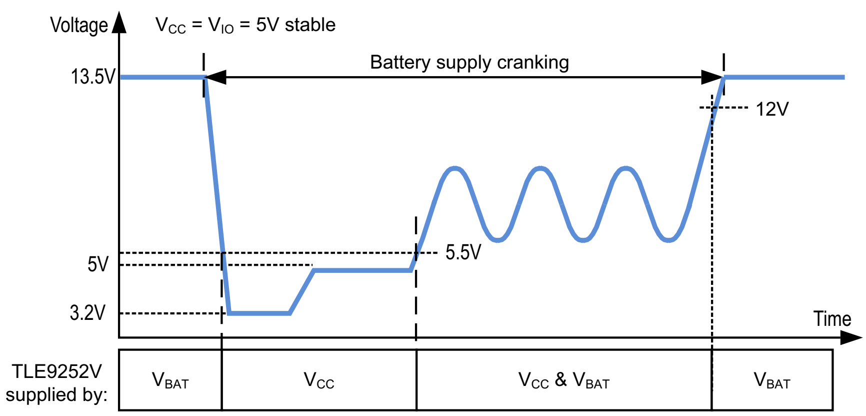


Figure 16 V_{BAT} battery supply cranking with stabilized V_{CC} voltage example drawing

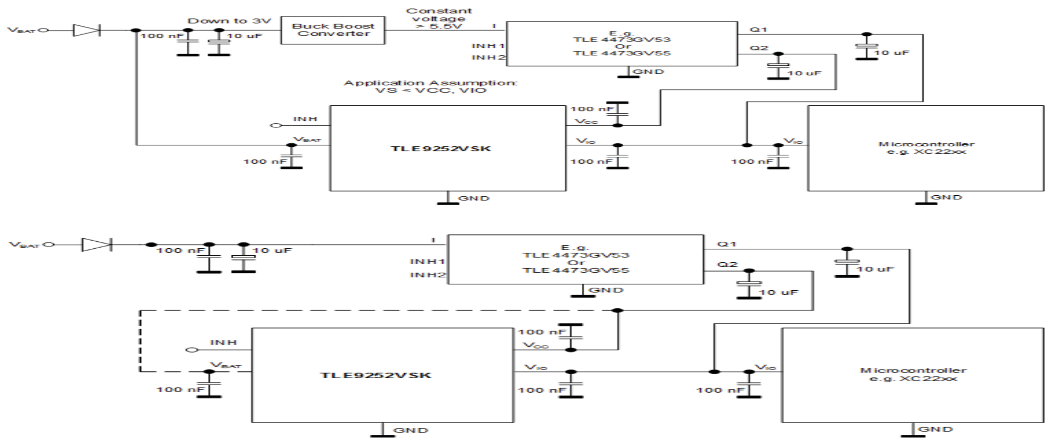


Figure 17 V_{BAT} battery supply cranking with stabilized V_{CC} voltage example application

5.4 V_{IO} Feature

TLE9252V offers a V_{IO} supply pin, which is a voltage reference input for adjusting the voltage levels on the digital input and output pins to the voltage supply of the microcontroller. In order to use the V_{IO} feature, connect the power supply of the microcontroller to the V_{IO} input pin. Depending on the voltage supply of the microcontroller, TLE9252V can operate with the V_{IO} reference voltage input within 3.0 V $< V_{IO} <$ 5.5 V.

5.5 Power-up Sequence for V_{BAT}, V_{CC} and V_{IO}

As TLE9252V has V_{BAT}, V_{CC} and V_{IO} supply pin, this chapter describes possible scenarios for powering up the device. V_{BAT} supplies the state machine of TLE9252V. V_{CC} supplies the transmitter (and the state machine in case of V_{BAT} drops). V_{IO} is the reference voltage and adapts the input thresholds and output voltage to the microcontroller interface. The Local wake-up detection is enabled if $V_{BAT} > V_{BAT\_UV}$. There is no limitation for the start-up sequence for TLE9252V:

- Scenario 1: If V_{BAT} is supplied first the internal state machine starts to work for $V_{BAT} > V_{BAT\_POD}$ (3V $< V_{BAT\_POD} <$ 4.8V). The mode of operation can be changed by the mode selection pins NSTB and EN if $V_{IO} > V_{IO\_UV}$. The transmitter of TLE9252V remains disabled in Normal-operating Mode if $V_{CC} < V_{CC\_UV}$ and also in all other modes.
- Scenario 2: If V_{CC} is supplied first, the internal state machine starts to work for $V_{CC} > V_{CC\_POD}$ (3.0V $< V_{CC\_POD} <$ 4.0V). The mode of operation can be changed by the mode selection pins NSTB and EN if $V_{IO} > V_{IO\_UV}$. The transmitter of TLE9252V remains disabled in Normal-operating Mode if $V_{CC} < V_{CC\_UV}$ and also in all other modes.
- Scenario 3: If V_{IO} is supplied first, the device remains unsupplied. As V_{IO} is only a reference input voltage TLE9252V remains switched off for $V_{CC} < V_{CC\_POD}$ OR $V_{BAT} < V_{BAT\_POD}$. The transmitter output stage is supplied if $V_{CC} > V_{CC\_UV}$.

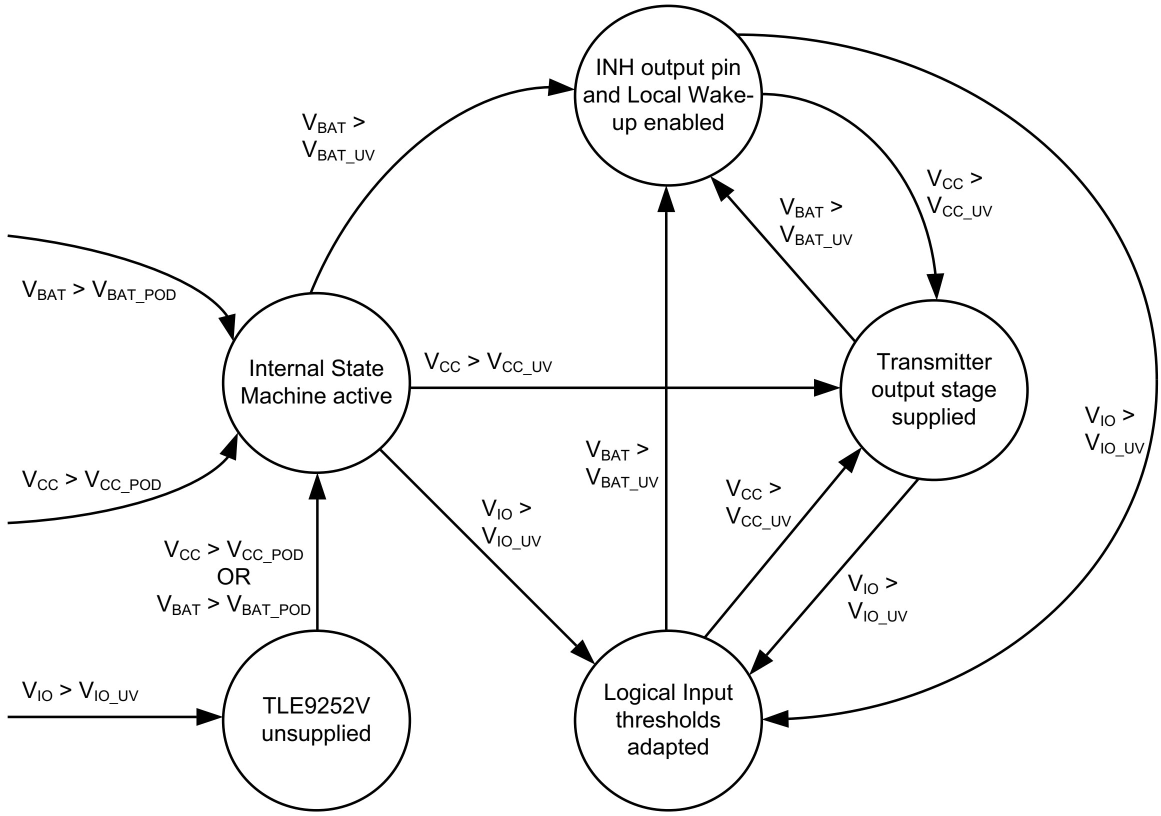


Figure 18 Power-up Scenarios for TLE9252V

5.6 Wired OR with INH output pin

The INH pin can be used to control the supply voltage of an ECU. Therefore the INH pin is connected to the mode control input of a power supply IC (e.g. LDO or DCDC). In Sleep Mode the INH is High-Z and due to the usually integrated pull-down resistor on the mode control input pin of the power supply IC, the supply control IC is switched off. This feature can be used to safe current of the ECU in low-power mode.

The INH output voltage is related to the battery supply voltage. When $V_{BAT} > V_{BAT\_UV}$ the undervoltage detection timer t_{UV_VIO} and t_{UV_VCC} will be armed. For power-up sequences it is very important to make sure the V_{CC} and V_{IO} power supply are already functional when $V_{BAT} > V_{BAT\_UV}$, because an undervoltage on V_{CC} or V_{IO} will trigger a mode change to Sleep Mode when no communication is monitored on the HS CAN bus and a long-term undervoltage time-out on V_{CC} ($t > t_{VCC\_UV\_T}$) or V_{IO} ($t > t_{VIO\_UV\_T}$) has been detected. As the TLE9252V is supposed to be used in permanently battery supplied ECUs, the INH pin follows the battery voltage. On ECU Level this has to be considered for test cases as for example "E-07 Slow decrease and increase of the voltage V_{BAT}". If more than one TLE9252V is supposed to control one power supply IC, then the INH outputs can be connected in wired-OR configuration (see **Figure 19**).

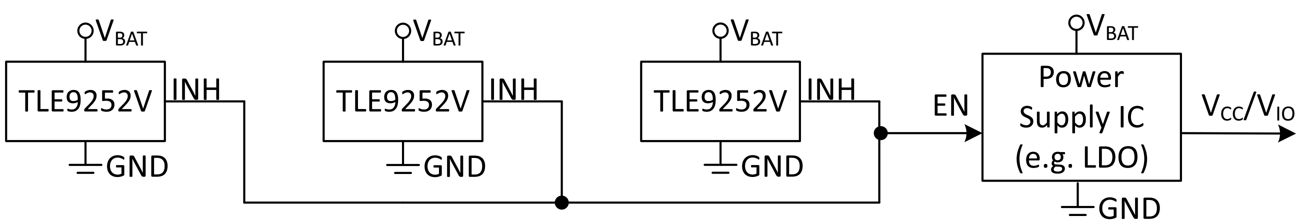


Figure 19 Multiple INH controlled power supply example

5.7 Ground Shift

Due to ground shift the GND levels of CAN transceivers within a network may vary. Ground shift occurs in high current applications or in modules with long GND wires. Because the transmitting node has its GND shifted to V_{Shift}, the recessive voltage level V_{rec} from the chassis ground is no longer 2.5 V but $V_{rec} + V_{shift}$. The same ground shift voltage V_{Shift} must be taken into account for the dominant signal. Because CAN uses a differential signal and because of the wide common mode range of +/-12 V for Infineon transceivers, any CANH and CANL DC works. Only the defferntial voltage (CAN_H - CAN_L) is relevant for the receiver. **Figure 20** shows a typical CAN signal with a DC ground shift of +2V.

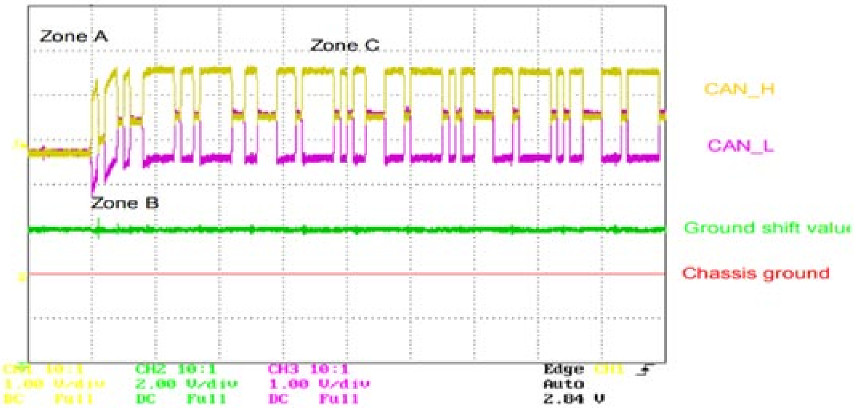


Figure 20 DC ground shift signal

Zone A : Shows the recessive voltage of the system, so close to the nominal recessive value of 2.5V

Zone B : When the transmitter starts to communicate the signal grows quickly.

Zone C : The communication is stabilized, and the recessive voltage reaches the value, as computed on equation below. The recessive CAN bus level V_{rec} during a ground shifted node transmitting is equal to the average recessive voltage level of all transceivers:

$V_{rec} = [(V_{rec\_1} + V_{Shift\_1}) + (V_{rec\_2} + V_{Shift\_2}) + (V_{rec\_3} + V_{Shift\_3}) + ... + (V_{rec\_n} + V_{Shift\_n})]/n$

n: number of connected CAN nodes

V_{rec_1}, V_{rec_2}, .., V_{rec_n}: specific recessive voltage level of the transceiver at nodes 1, 2, .. n

V_{Shift_1}, V_{Shift_2}, ..., V_{Shift_n}: specific ground shift voltage level of the transceiver at nodes 1, 2, .. n

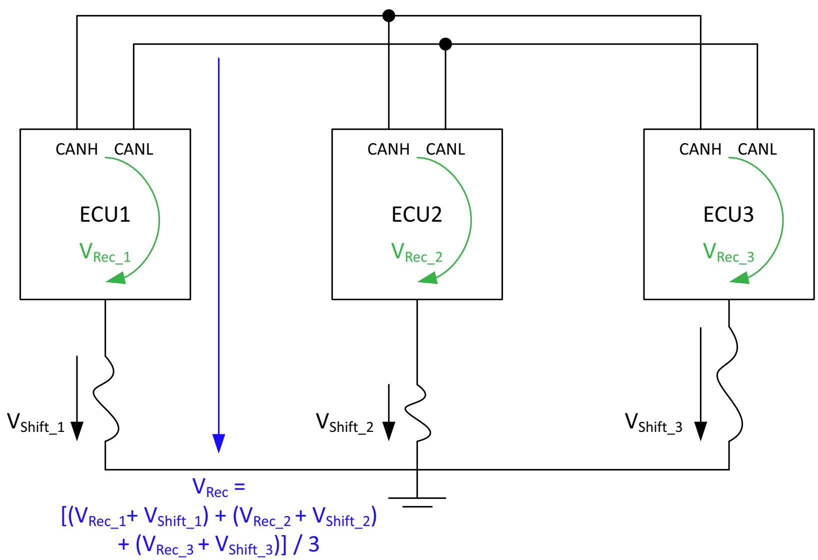


Figure 21 Ground Shift on three nodes (system view)

6 Mode Control Hints

The modes of operation of TLE9252V are controlled by the pins EN and NSTB.

6.1 Mode Changes by EN and NSTB pin

The Mode of operation is set by the mode selection pin NSTB and EN. **Figure 22** shows all possible mode changes by EN and NSTB pin.

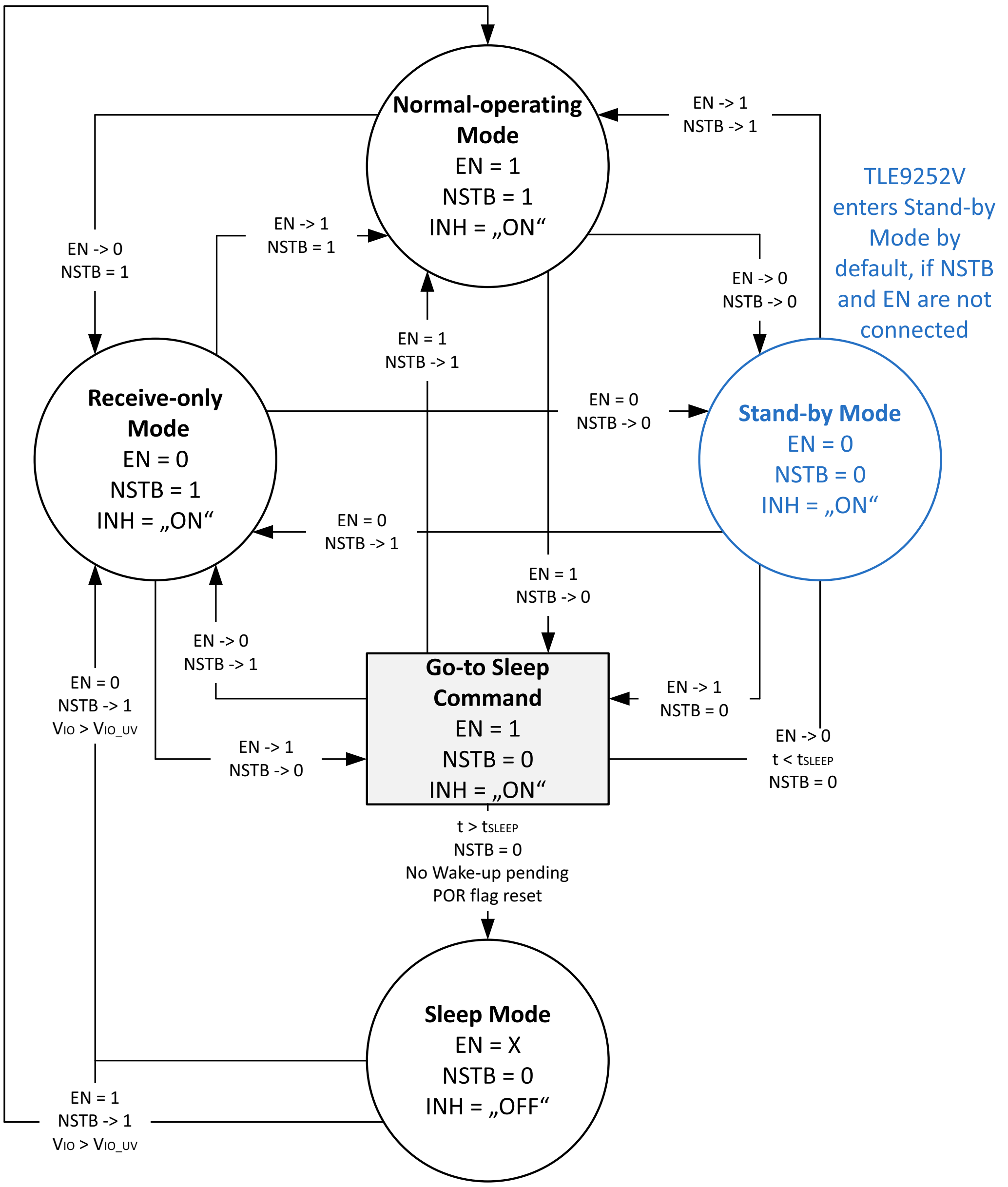


Figure 22 Mode changes by EN and NSTB pin

A mode change from Normal-operating Mode to Stand-by Mode is triggered if EN and NSTB are set to “low”. A mode change from Stand-by Mode to Normal-operating Mode is triggered if EN and NSTB are set to “high”. If the software routine does set the output sequentially, for these mode changes it is important to make sure mode pins are set within t < 1µs. This will ensure a direct mode change from Normal-operating Mode to Stand-by Mode or vice versa. If the delay time between setting the mode pins EN and NSTB to “high” or “low” is higher than 1µs, the TLE9252V may perform an indirect mode change from Normal-operating Mode to Stand-by Mode via Receive-only Mode or Go-to-Sleep Command, which will cause longer mode change delay timing.

6.1.1 EN and NSTB unconnected

By default the EN input pin and the NSTB input pin are "low" due to the internal pull-down current source to GND. Due to the pull-down current sources on NSTB and EN the device enters Stand-by Mode by default in order to reduce current consumption in case of a failure (see **Figure 22**).

6.1.2 EN and NSTB connected to V_{IO} supply

For applications, which do not require the Low-power Management and Receive-only Mode, the EN and NSTB input pins can be directly connected to V_{IO} supply. In this case when EN and NSTB input pins are directly connected to V_{IO} supply, the device will enter Normal-operating Mode if $V_{IO} > V_{IO\_UV}$. If $V_{IO} < V_{IO\_UV}$ then the device is in Low-power Mode (Stand-by Mode or Sleep Mode).

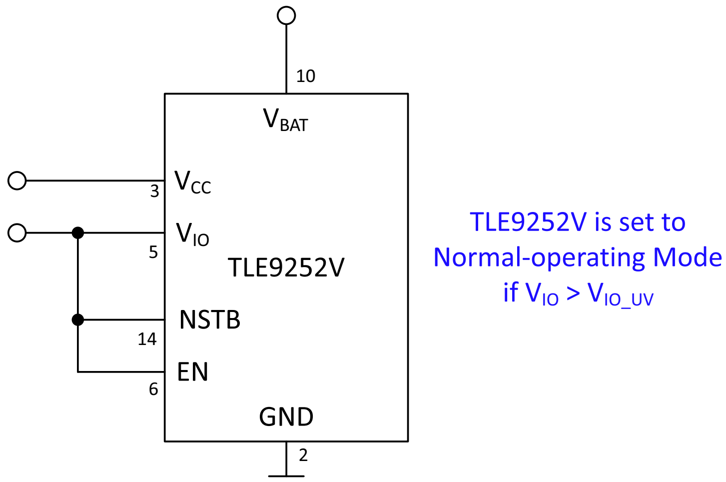


Figure 23 EN and NSTB input pins connected to V_{IO}

6.2 Behavior of RxD and NERR 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 RxD and NERR output pin during mode change:

- During mode changes from Stand-by Mode to Normal-operating Mode AND from Stand-by Mode to Receive-only Mode, the RxD output pin is set to logical "high" and does not reflect the status on the CANH and CANL input pins.
- During mode changes from Normal-operating Mode to low-power modes (Stand-by Mode, Sleep Mode, Go-to-Sleep Command) the RxD output pin is set to logical "high".
- During mode changes from Receive-only Mode to low-power modes (Stand-by Mode, Sleep Mode, Go-to-Sleep Command) the RxD output pin is set to logical "high".
- During mode changes from Receive-only Mode to Normal-operating Mode OR Normal-operating Mode to Receive-only Mode the RxD output pin reflects the status on the HS CAN Bus.
- 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.
- The diagnostics on NERR pin is updated after t_{Mode} has expired, when the mode transition is completed.
- 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.

6.3 Mode Change to Normal-operating Mode (TxD input signal "low")

After a mode change from any mode to Normal-operating Mode, the transmitter path is enabled if a "high" signal on TxD input pin is applied. If during a mode change to Normal-operating Mode a "low" signal is applied on TxD input pin the transmitter path is kept disabled as long as logical "high" is monitored on TxD input pin. In this case a permanent dominant signal is blocked in order not to disturb the bus communication (see **Figure 24**). Once the TxD input signal goes "high" the transmitter is enabled in Normal-operating Mode.

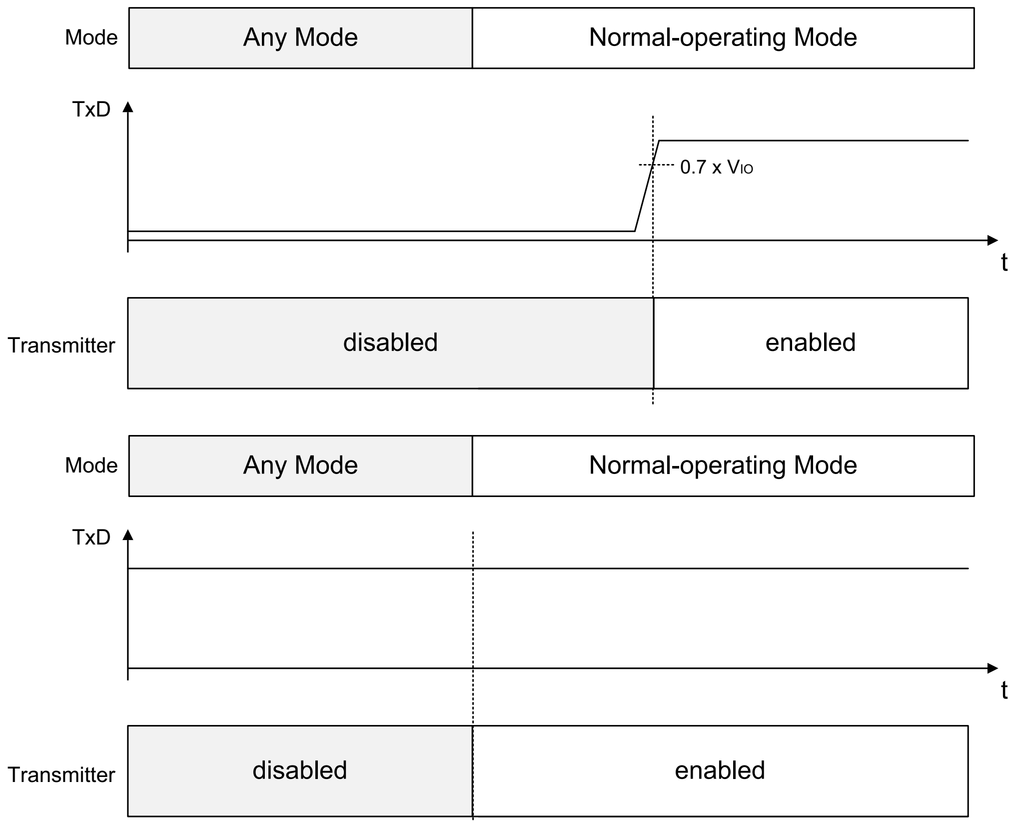


Figure 24 Mode change to Normal-operating Mode with "low" signal on TxD

6.4 Mode Change Transitions

Figure 25 shows mode change transitions depending on NSTB and EN input pin assuming V_{IO} is in the functional range. During mode changes from low-power mode to Normal-operating Mode or Receive-only Mode, the RxD output pin is set to logical “high” and does not reflect the status on the CANH and CANL input pins

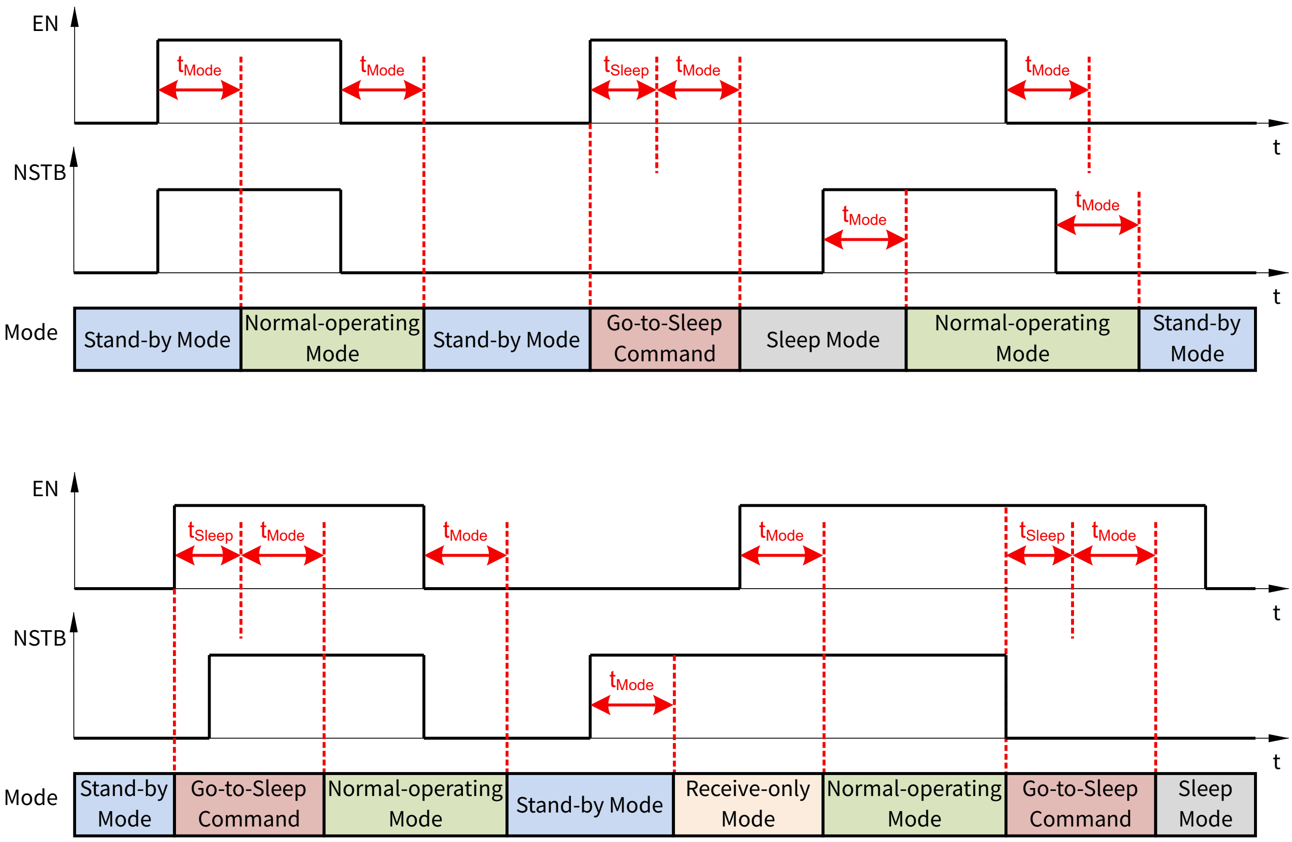


Figure 25 Mode change transitions

6.5 Autonomous Bus Voltage Biasing and mode change

The autonomous bus voltage biasing was introduced for improving complete network EMC performance and increasing the reliability of communication performance in networks using CAN networks. The Bus Voltage Biasing is active in normal mode and is controlled by the differential voltage V_{Diff} between CANH and CANL and detected network activity ($t_{Silence}$)in low-power modes. For detailed explanation of restart and expiration condition of $t_{Silence}$ please see **Chapter 6.6**.

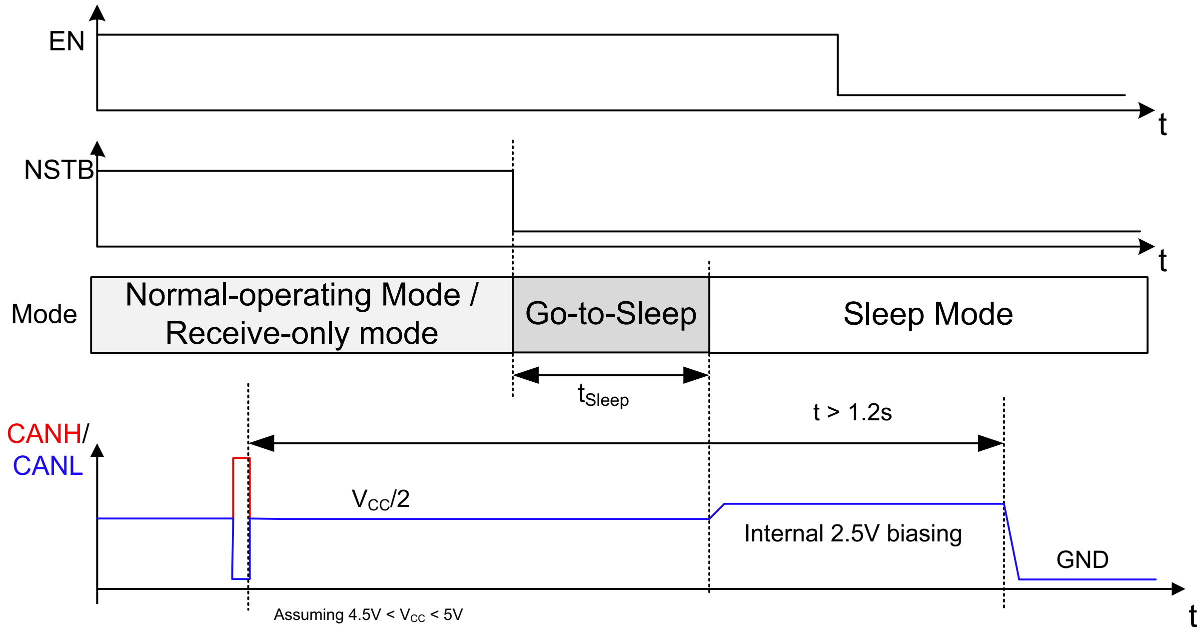


Figure 26 Bus Voltage Biasing change from V_{CC}/2 to internal 2.5V

In Normal-operating Mode and Receive-only Mode the bus biasing is active and connected to V_{CC}/2. When changing the mode of operation to Sleep or Stand-by Mode from Normal-operating Mode or Receive-only mode, the bus biasing is connected to the internal 2.5V (min. 2.0V, max. 3.0V) biasing, if $t_{Silence}$ has not expired. This change of the bus biasing from V_{CC}/2 to 2.5V can be monitored on the recessive bus biasing level as shown on **Figure 26**. If there has been no activity on the bus for longer than $t_{Silence}$, the bus pins are biased towards GND via the internal resistors.

The same behavior of the recessive bus biasing voltage can be observed for:

- Mode changes from Stand-by Mode to Receive-only mode or Normal-operating Mode. In this case the recessive voltage level changes from internal 2.5V to V_{CC}/2.
- V_{CC} undervoltage in Normal-operating Mode or Receive-only Mode.In this case the recessive voltage level changes from internal V_{CC}/2 to 2.5V. If V_{CC} recovers the biasing is connected to V_{CC}/2 again.

6.6 Autonomous bus biasing ($T_{Silence}$ timer)

Sleep Mode and Stand-by Mode:

The timer $t_{Silence}$ controls the bus biasing in low-power modes: Stand-by Mode and Sleep Mode. In low-power mode by default the bus biasing is connected to GND (Bus Bias off). Only if a valid wake-up pattern has been detected the $t_{Silence}$ timer is restarted and the bus biasing is connected to 2.5V. If $t_{Silence}$ has expired, the bus biasing is connected to GND: Bus Bias off. After Power-on-Reset $t_{Silence}$ is by default in expired state.

Normal-operating Mode and Receive-only Mode:

In Normal-operating Mode and Receive-only Mode the bus biasing is always connected to $V_{CC}/2$ or internal 2.5V ($V_{CC} < V_{CC\_UV}$) independent on the status of $t_{Silence}$. A single transition from "recessive" state to "dominant" state or vice versa with a pulse length of t > t_{Filter} restarts the $t_{Silence}$ timer in Normal-operating Mode and Receive-only Mode. In case $t_{Silence}$ is expired and a mode change is triggered from Normal-operating Mode or Receive-only Mode to Stand-by Mode or Sleep Mode the bus biasing is immediately connected to GND after t_{Mode}. In case $t_{Silence}$ is not expired and a mode change is triggered from Normal-operating Mode or Receive-only Mode to Stand-by Mode or Sleep Mode the bus biasing is connected internal 2.5V after t_{Mode} (see **Chapter 6.5**).

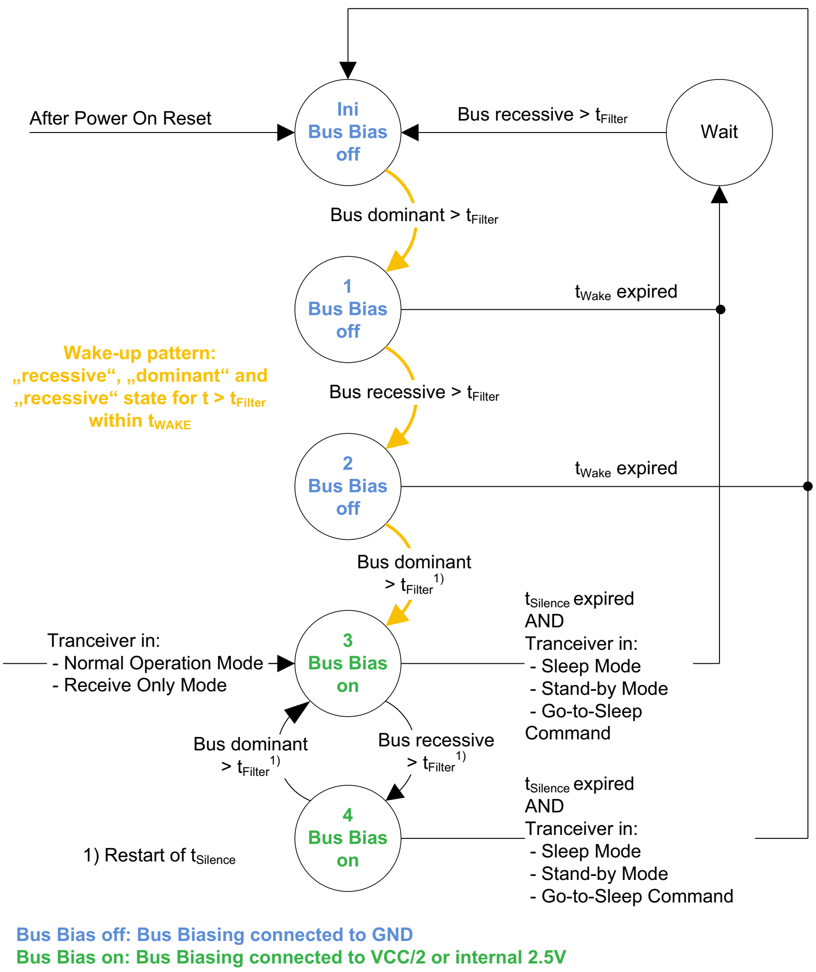


Figure 27 Flowchart for $t_{Silence}$

6.7 TLE9252V vs. TLE6251-3G differences

TLE9252V is the CAN FD successor part of TLE6251-3G. Major differences/improvements of TLE9252V are:

- CAN FD up to 5Mbit/s compliant to ISO11898-2 (2016)
- Optimized EMC performance fulfilling stringent IEC62228-3 requirements
- Improved quiescent current consumption in Sleep Mode: max. 26µA
- Local Failure diagnostics differentiation (see TLE9252V Diagnostics Application Note)

The pin-out of both devices is the same and the functionality is similar. Nevertheless there are small differences, which will be described in this chapter in order to enable a smooth and easy software adaption when changing from TLE6251-3G to new TLE9252V.

Table 8 Behavioral differences TLE9252V vs. TLE6251-3G

Condition	TLE9252V	TLE6251-3G
EN = “high” NSTB = “low” Wake-up event in Sleep Mode	After t_{Sleep} has expired the TLE9252V goes to Sleep Mode. If in Sleep Mode a wake-up is detected the device goes to Stand-by Mode and remains in Go-to-Sleep Mode (EN = “high”, NSTB = “low”). The INH pin is switched on and the wake-up is indicated on the RxD and NERR output pin.	After t_{HSLP} has expired the TLE6251-3G goes to Sleep Mode. If in Sleep Mode a wake-up is detected the device indicates a wake-up on RxD and NERR output pin, but the INH is not switched on as long as EN = “high”, NSTB = “low”. In order to switch on INH, the EN input pin has to be set to “low”.
First power-up NSTB = EN = “low” Wake-up event in Stand-by Mode	When first time powering up the device $V_{BAT} > V_{BAT\_POD}$ the TLE9252V enters Stand-by Mode. The POR Flag is set and can be read out in Receive-only Mode. A wake-up event will be indicated on the RxD and NERR output in Stand-by Mode after first power-up.	When first time powering up the device $V_S > V_{S,Pon}$ the TLE6251-3G enters Stand-by Mode. The POR Flag is set and can be read out in Receive-only Mode. After first power-up a wake-up event will not be indicated on the RxD and NERR output in Stand-by Mode. Once the POR Flag is reset by entering Normal-operating Mode, a wake-up will be indicated in Stand-by Mode.
EN = NSTB = “low” Device in Sleep Mode V_{CC} and V_{IO} in functional range	Only if NSTB is set to “high” a mode change by host command will be triggered. If EN is set to “high” in Sleep Mode this host command is blocked and the TLE9252V remains in Sleep Mode. For a mode change via host command on NSTB pin only V_{IO} has to be in the functional range.	If NSTB or/and EN is set to “high” a mode change will be triggered. If only EN is set to “high” the TLE6251-3G changes to Go-to Sleep Command and INH is switched on. After t_{HSLP} expires the TLE6251-3G goes to Sleep Mode again. For mode changes via Host command V_{IO} and V_{CC} have to be in the functional range.

7 Wake-up indication

In order to reduce current consumption of permanently supplied applications the TLE9252V can be set to Sleep Mode. The TLE9252V offers the INH output pin, which can be used to control the ECU power supply. In Sleep Mode the INH pin is switched off, which will result in switching off the ECU power supply. In order to reactivate the ECU, the TLE9252V includes wake-up functions, which will set the TLE9252V to Stand-by Mode. In Stand-by Mode the INH pin is switched on to reactivate the ECU power supply. There are different wake-up sources in Sleep Mode, Go-to-Sleep Command and Stand-by Mode:

- Wake-up Pattern (WUP): Wake-up detection via HS CAN bus (see **Chapter 7.1**)
- Local Wake-up: Rising or falling edge on WAKE-pin (see **Chapter 7.2**)

Once a wake-is detected the TLE9252V moves to Stand-by Mode and indicates the wake-up event via RxD and NERR output pin. The status of RxD and NERR output pin are different, depending on the wake-up source. This feature is implemented in order to differentiate the wake-up source (detailed description see **Chapter 7.3**).

7.1 Wake-up Pattern (WUP) Detection

The TLE9252V includes the bus wake-up pattern (WUP) detection feature. In Sleep Mode, Go-to-Sleep Command and Stand-by mode the TLE9252V monitors activity on the CAN bus. If TLE9252V detects a valid wake-up pattern, TLE9252V will enter Stand-by Mode from Sleep Mode.

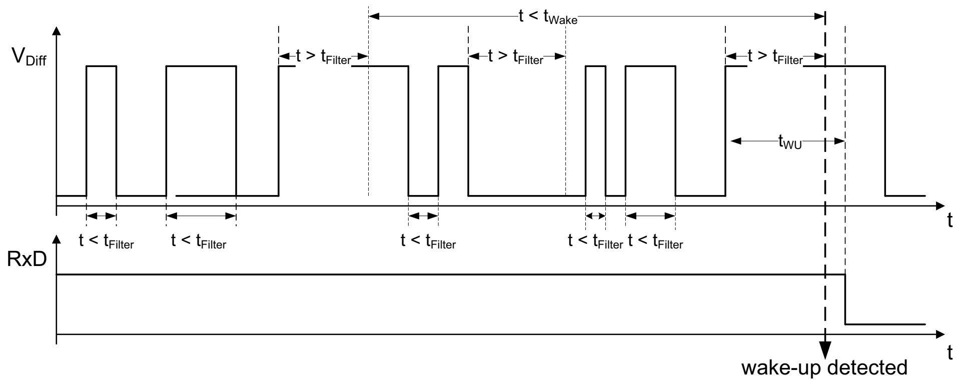


Figure 28 WUP Detection example in CAN message

Within maximum wake-up time t_{WAKE}, the wake-up pattern must contain a dominant signal with the pulse width t_{Filter}, followed by a recessive signal with the pulse width t_{Filter} and another dominant signal with the pulse width t_{Filter}. Wake up pattern detection is only reset after t_{WAKE} expires. The wake-up pattern is valid also with additional dominant and recessive states shorter than t_{Filter}, which occur within the time period t_{WAKE} e.g. within a real CAN or CAN FD message (see **Figure 28**). The RxD output pin remains "high" until a valid wake-up pattern is detected. A wake-up pattern detection is indicated on the RxD and NERR output pin as logical "low".

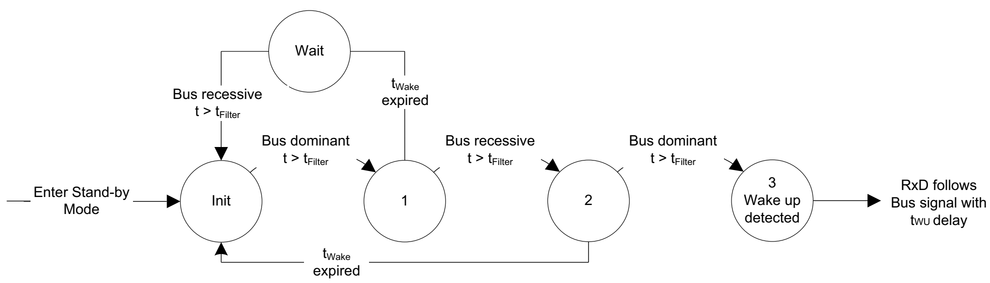


Figure 29 WUP Detection according to ISO 11898-2 (Edition 2016)

7.1.1 Benefit of Infineon Wake-up Pattern (WUP) implementation

Using CAN Flexible Data Rate also requires the usage of the ISO Frame Format CAN Flexible Data Rate Protocol for a save application. The Protocol Changes from Classical CAN Frame to CAN FD Frame Format implies also new Control Field bits (Flexible Data Rate Frame Indicator Bit, Bit Rate Switch, Remote Request Substitution Bit, Error State Indicator Bit). This has significant impact on the wake-up behavior of CAN transceivers. Former the CAN filter activity has been defined as 0.5µs < t_{Filter} < 5µs. This specification is also included in the new ISO 11898-2 standard as "CAN activity filter long". Due to the changed protocol, there has been introduced as well the "CAN activity filter time short" defined as 0.15µs < t_{Filter} < 1.8µs which ensures a wake-up of the transceiver in low-power Mode for 500kbit/s arbitration rate.

Therefore Infineon's TLE9252V has the improved wake-up filter time specified as 0.5µs < t_{Filter} < 1.8µs in order to ensure a wake-up with CAN Flexible Data-Rate Frames on the HS CAN Bus. A minimum of t_{Filter} > 0.5µs offers a high robustness against transients and noise on the HS CAN Bus.

Table 9 ISO11898-2: 2016 wake-up pattern filter specification

Description	Parameter	min	max	Unit	Comment
CAN activity filter time long	t_{filter}	0.5	5.0	µs	Maximum value of t_{Filter} recommended for Classical CAN
CAN activity filter time short	t_{filter}	0.15	1.8	µs	Maximum value of t_{Filter} recommended for CAN FD

Using Infineon's TLE9252V Transceiver for CAN FD communication ensures a wake-up for every possible Classical CAN Frame and CAN Flexible Data Rate Frame (example measurement see **Figure 30**).

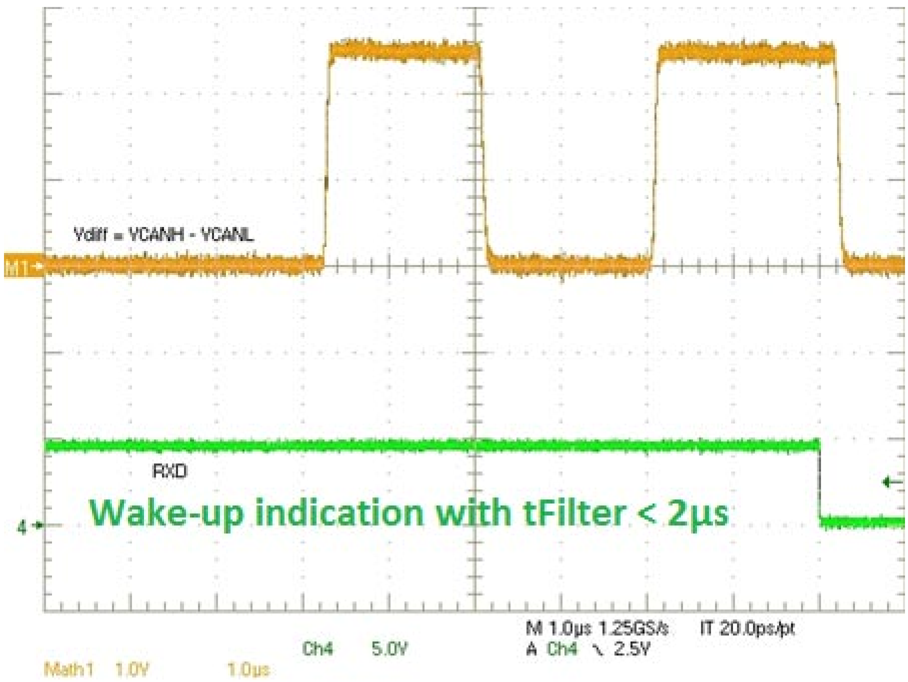


Figure 30 Wake-up indication of TLE9252V in Stand-by Mode

7.1.2 Bus Wake-up and Mode Change

The example in **Figure 31** shows a WUP detection with a mode change while the bus is "dominant" and the TxD input signal is set to logical "high".

After a valid WUP detection the internal Wake-up flag is set. The RxD output pin goes logical "low" when a valid WUP has been detected. During the mode transition from Stand-by mode to Normal-operating mode the RxD output is blocked and set to logical "high" with a delay of t_{RxD_Rec}. After the transition time t_{Mode} the RxD output pin is released again and follows the "dominant" signal on the HS CAN Bus.

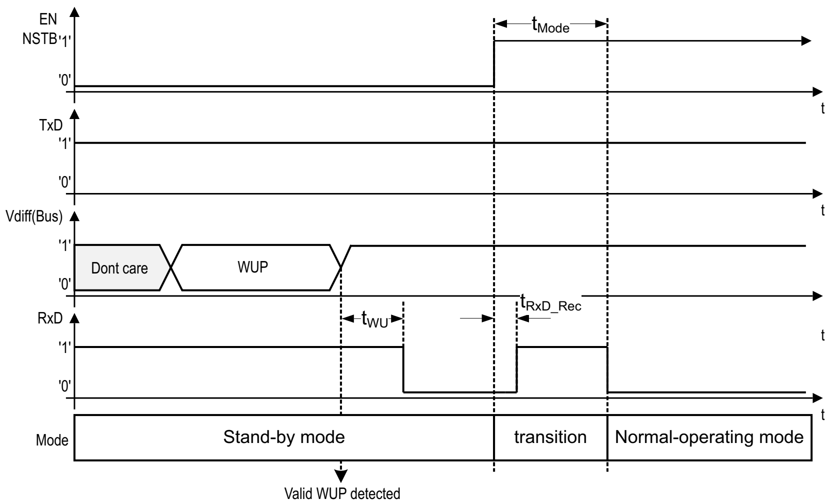


Figure 31 Mode change timing while Bus "dominant"

7.2 Local Wake-up

A local wake-up is the second wake-up source, which causes a wake-up of the TLE9252V. The WAKE input pin works bi-sensitive, meaning it is able to detect a rising and falling edge as a wake-up event. The Local Wake-up detection works only for $V_{BAT} > V_{BAT\_UV}$, which means during battery supply cranking below $V_{BAT} < V_{BAT\_UV}$ the local wake-up detection is disabled. The filter time t_{WAKE_filter} is implemented to protect the TLE9252V against unintended Wake-Ups, caused by spikes on the WAKE pin. The wake-up thresholds $V_{WAKE,L}$ and $V_{WAKE,H}$ depend on the level of the V_{BAT} power supply.

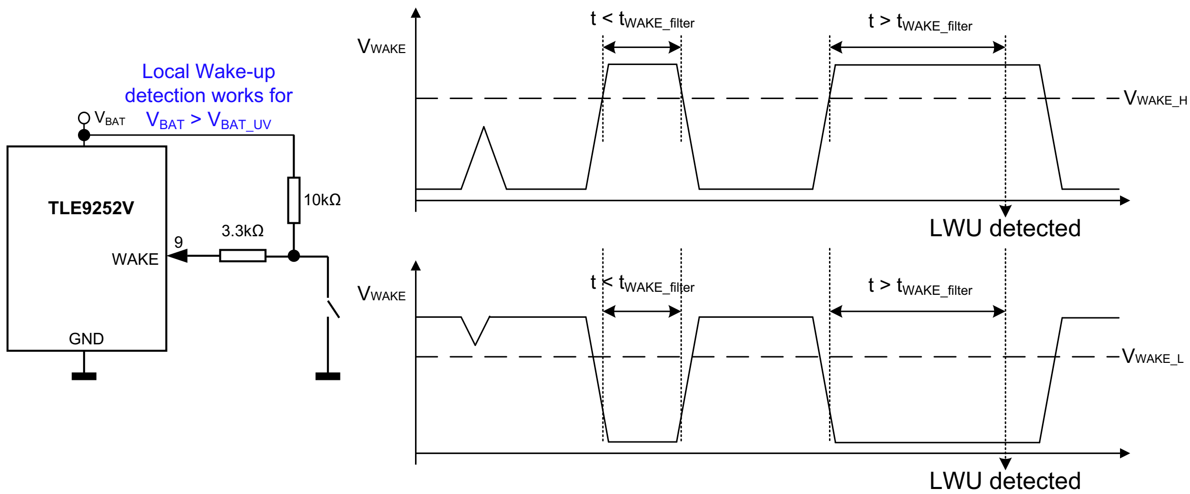


Figure 32 Local wake-up detection

7.3 Wake-up indication: RxD and NERR behavior

The RxD and NERR output pin will signal a wake up event to the microcontroller. In Sleep Mode, Stand-by Mode and Go-to-Sleep Command the default values of RxD and NERR are logical "high" if no wake-up event has been detected. If a valid wake up pattern (WUP) is detected, RxD and NERR are set to logical "low". If a Local wake-up (LWU) is detected only the RXD is set to logical "low". 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 35**). When entering Stand-by Mode from Power On Reset, NERR pin and RxD pin are set to logical "high" (see **Figure 36**).For detailed explanation of RxD and NERR behavior and example measurements please refer to TLE9252V Diagnostics Application Note.

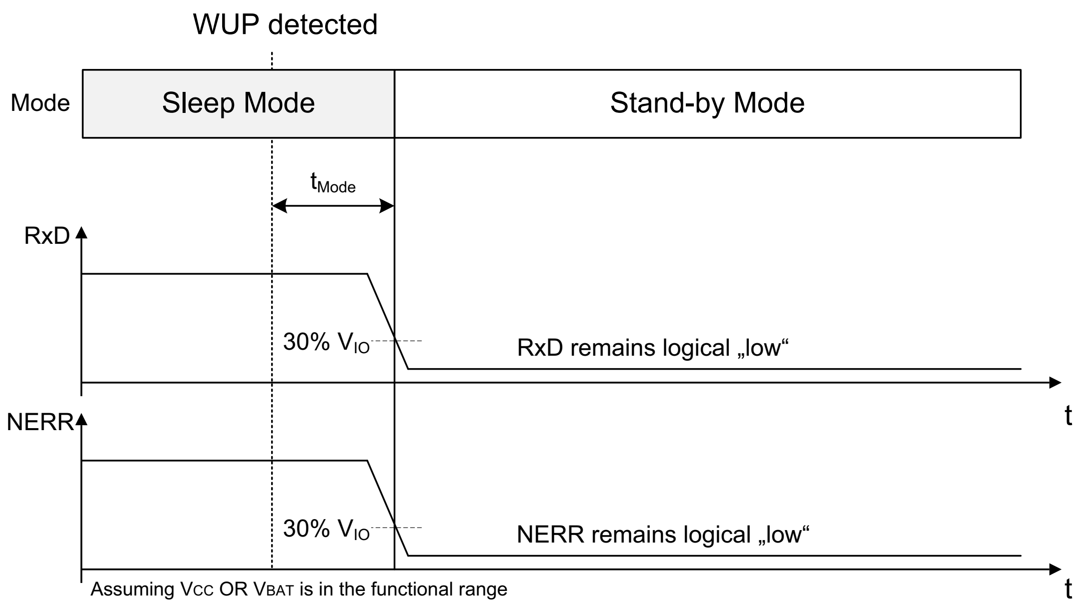


Figure 33 RxD and NERR: WUP detection (permanently supplied V_{IO})

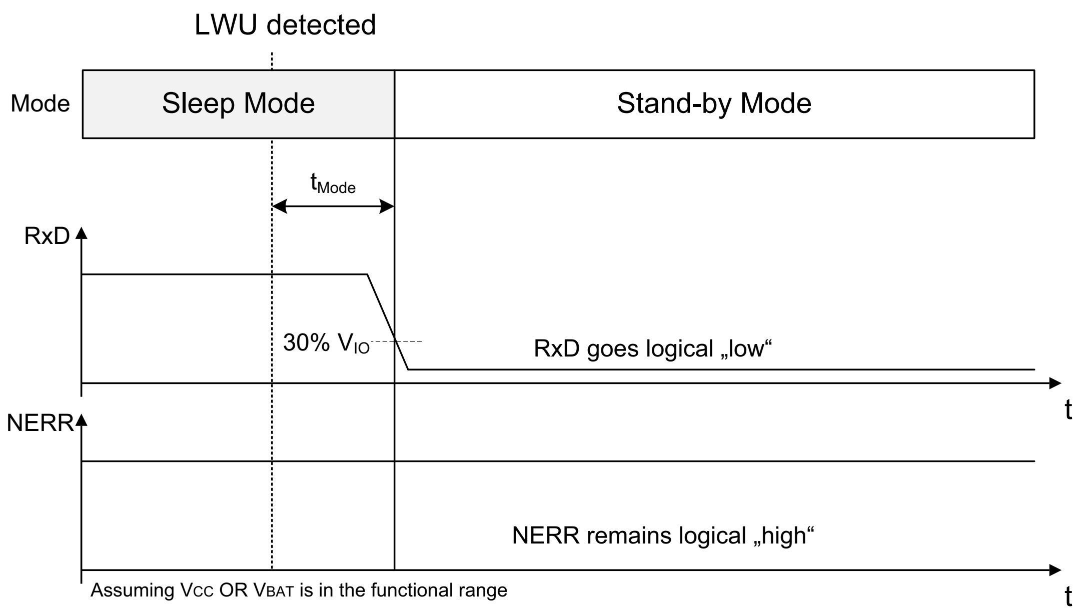


Figure 34 RxD and NERR: LWU detection (permanently supplied V_{IO})

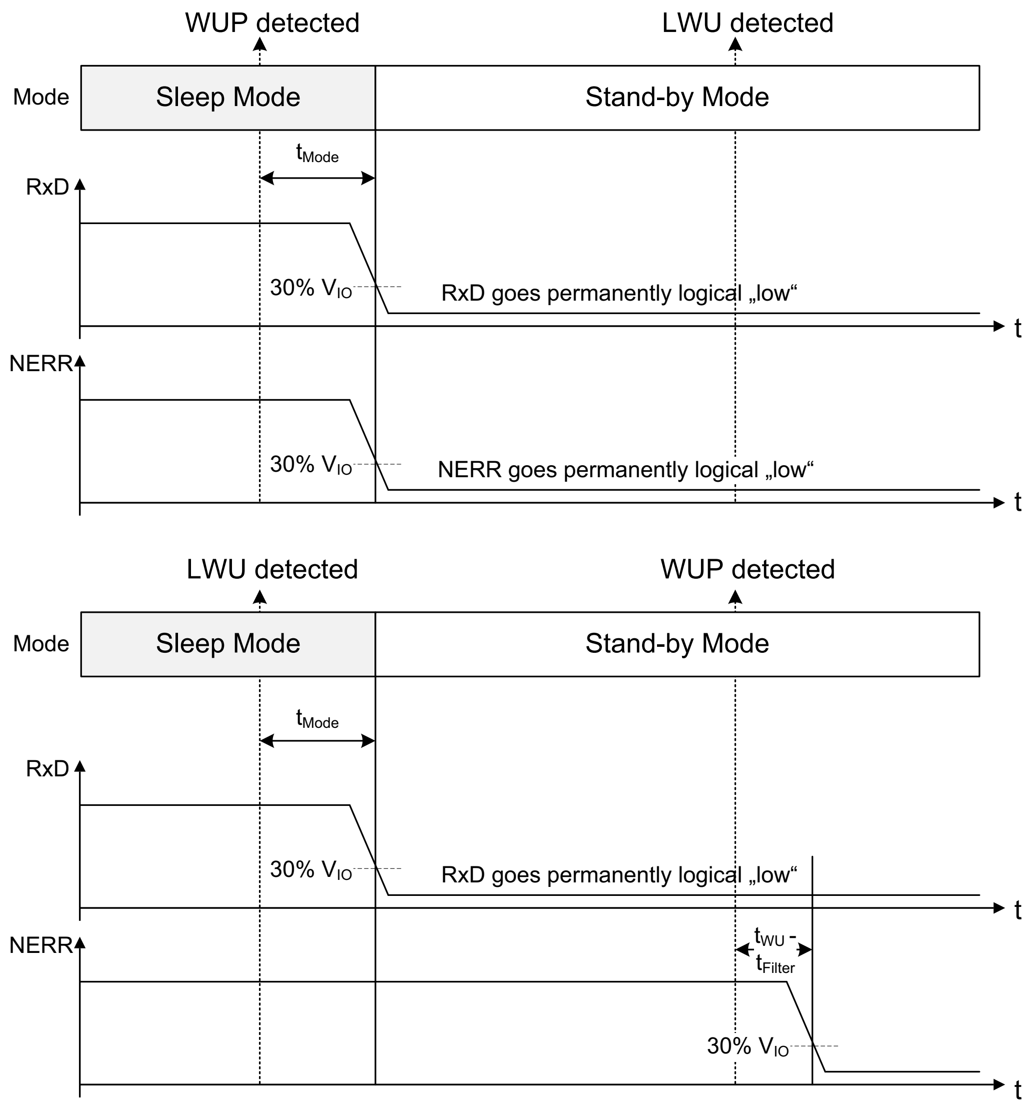


Figure 35 **RxD and NERR: WUP AND LWU detection (permanently supplied V_{IO})**

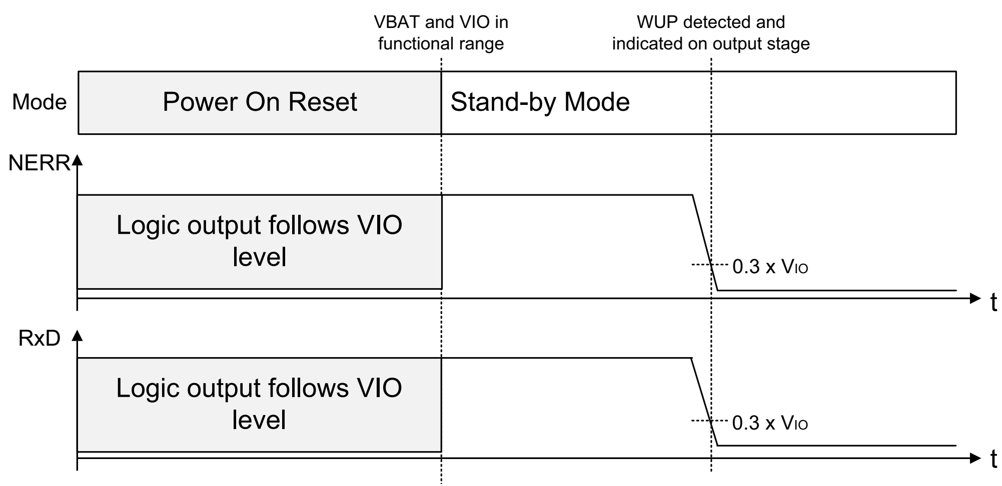


Figure 36 **NERR and RxD behavior when entering Stand-by Mode from Power-On-Reset**

7.4 Local Wake-up due to V_{BAT} rise if V_{CC} supplied

When V_{CC} and V_{IO} is supplied (V_{CC} = 5V, V_{IO} = 3.0V ... 5V) the TLE9252V is functional. If then V_{BAT} is supplied a unintended wake-up pulse may be detected on the local WAKE input pin when placing a pull-down resistor to GND. A falling and rising edge on WAKE can also occur during V_{BAT} battery voltage cranking. In order to avoid an unwanted wake-up, if V_{BAT} rises, the WAKE pin should be connected via a pull-up resistor to V_{BAT}.

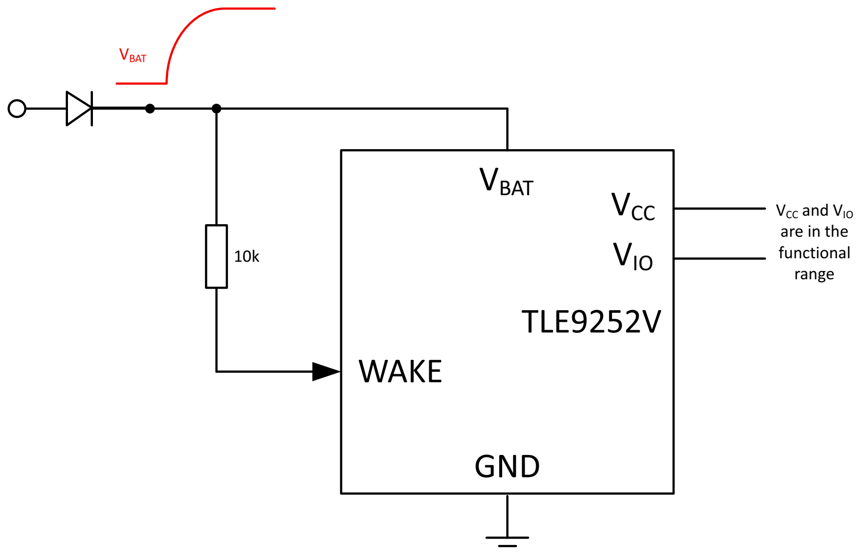


Figure 37 Circuitry to avoid unintended local wake-up

8 Fail Safe Features

TLE9252V has several fail-safe functions implemented as:

- Undervoltage detection on V_{BAT}, V_{CC} and V_{IO} (see **Chapter 8.1**)
- TxD "dominant" time-out detection (see **Chapter 8.2**)
- RxD recessive clamping detection (see **Chapter 8.3**)
- Overtemperature protection
- Short Circuit protection (see **Chapter 8.4**)

For detailed information and example measurements of diagnostic features of TLE9252V on RxD and NERR output pin please refer to TLE9252V Diagnostics Application Note.

8.1 Undervoltage detection

The TLE9252V has three independent undervoltage detections on V_{BAT}, V_{CC} and V_{IO}. These undervoltage events may have impact on the functionality of the device and also may change the mode of operation.

8.1.1 V_{BAT} undervoltage detection

The V_{BAT} battery supply undervoltage detection is by default active in every mode of operation except of Sleep Mode. In Sleep Mode the V_{BAT} undervoltage detection is enabled shortly if a Local Wake-up event is detected. In order to evaluate a valid Local wake-up event. A local wake-up event is valid if $V_{BAT} > V_{BAT\_UV}$. Below $V_{BAT} < V_{BAT\_UV}$ the local wake-up event is not valid and will not cause a wake-up. This feature is implemented in order to prevent false local wake-up events due to low battery supply voltage.

8.1.2 V_{CC} undervoltage detection

The V_{CC} supply undervoltage detection is active in Normal-operating Mode, Receive-only Mode, Stand-by Mode. In Normal-operating Mode, Receive-only Mode and Stand-by Mode if a $V_{CC} < V_{CC\_UV}$ undervoltage event is detected the transmitter is disabled. If no bus communication is monitored and the $t_{Silence}$ timer has expired, the device will go to Sleep Mode in order to reduce the current consumption (see **Figure 38**).

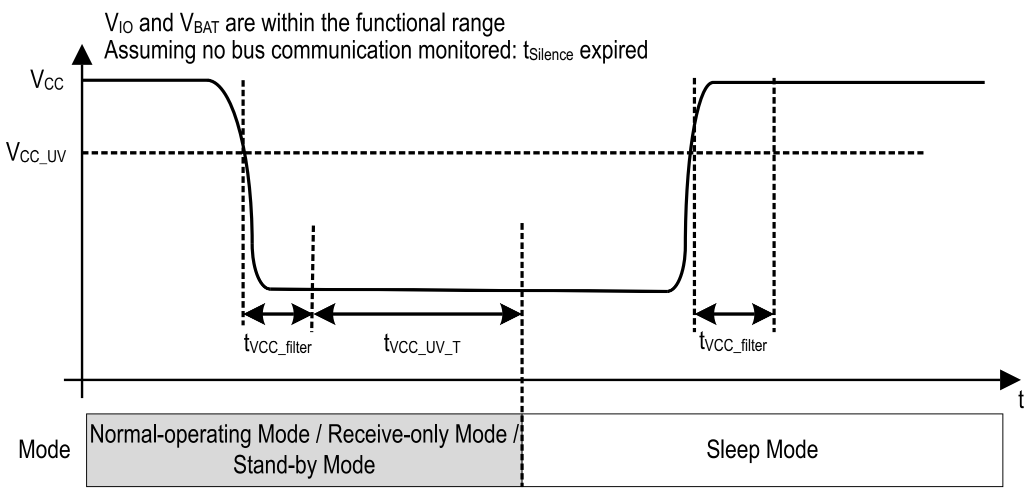


Figure 38 Mode Transition to Sleep Mode

If V_{BAT} is not connected and $V_{CC} < V_{CC\_POD}$ (3.0V < V_{CC_POD} < 4.0V), the TLE9252V will be switched off after t_{VCC_filter}. If V_{CC} recover ($V_{CC} > V_{CC\_POD}$) the TLE9252V enter Stand-by Mode by default (see **Figure 39**).

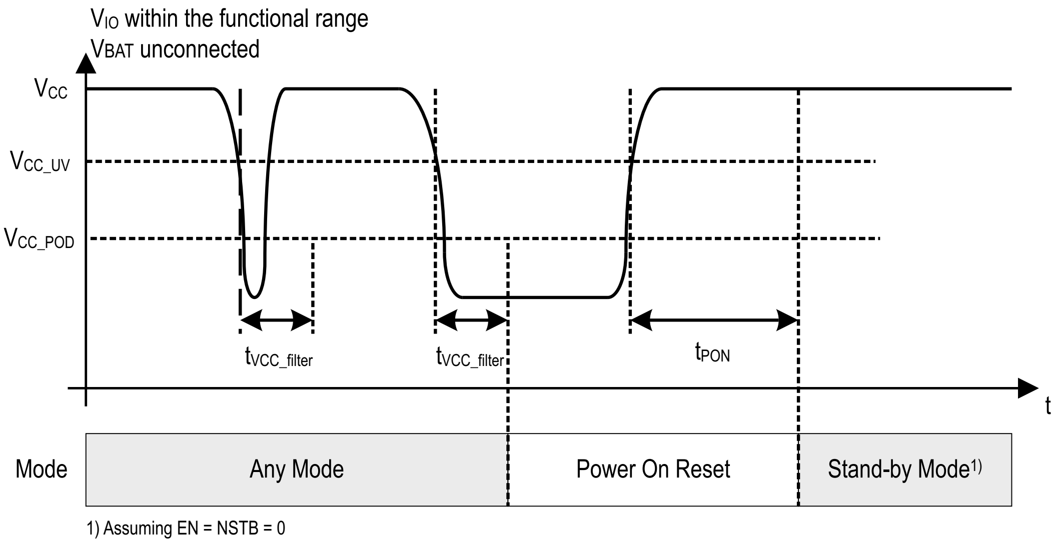


Figure 39 V_{CC} undervoltage detection (V_{BAT} unconnected)

- If the device moves to Sleep Mode due to a long-term undervoltage event on V_{CC} the device remains in Sleep Mode until a logical "0" to logical "1" transition on NSTB takes place. The EN signal state is evaluated when a rising edge on the NSTB pin is detected and the device moves to Receive-only Mode or Normal-operating Mode.
- From Sleep Mode a signal transition on NSTB from logical "low" to logical "high" is needed to trigger a mode change to Normal-operating Mode or Receive-only Mode when $V_{IO} > V_{IO\_UV}$.
- If in Sleep Mode due to a V_{CC} long-term undervoltage a WUP or LWU is detected, the device will change to Stand-by Mode. In Stand-by Mode the static input signal is evaluated and the device enters the mode of operation applied on the NSTB and EN pin accordingly.
- If the device moves to Sleep Mode due to a long-term undervoltage event on V_{IO} the device remains in Sleep Mode until V_{IO} recovers ($V_{IO} > V_{IO\_UV}$). If V_{IO} recovers the device moves back to the mode of operation which is applied by logic input signals on NSTB and EN pin. In case of NSTB = EN = 0 after a V_{CC} or V_{IO} undervoltage the device stays in Sleep Mode. In order to enter Stand-by Mode again a wake-up event is needed.

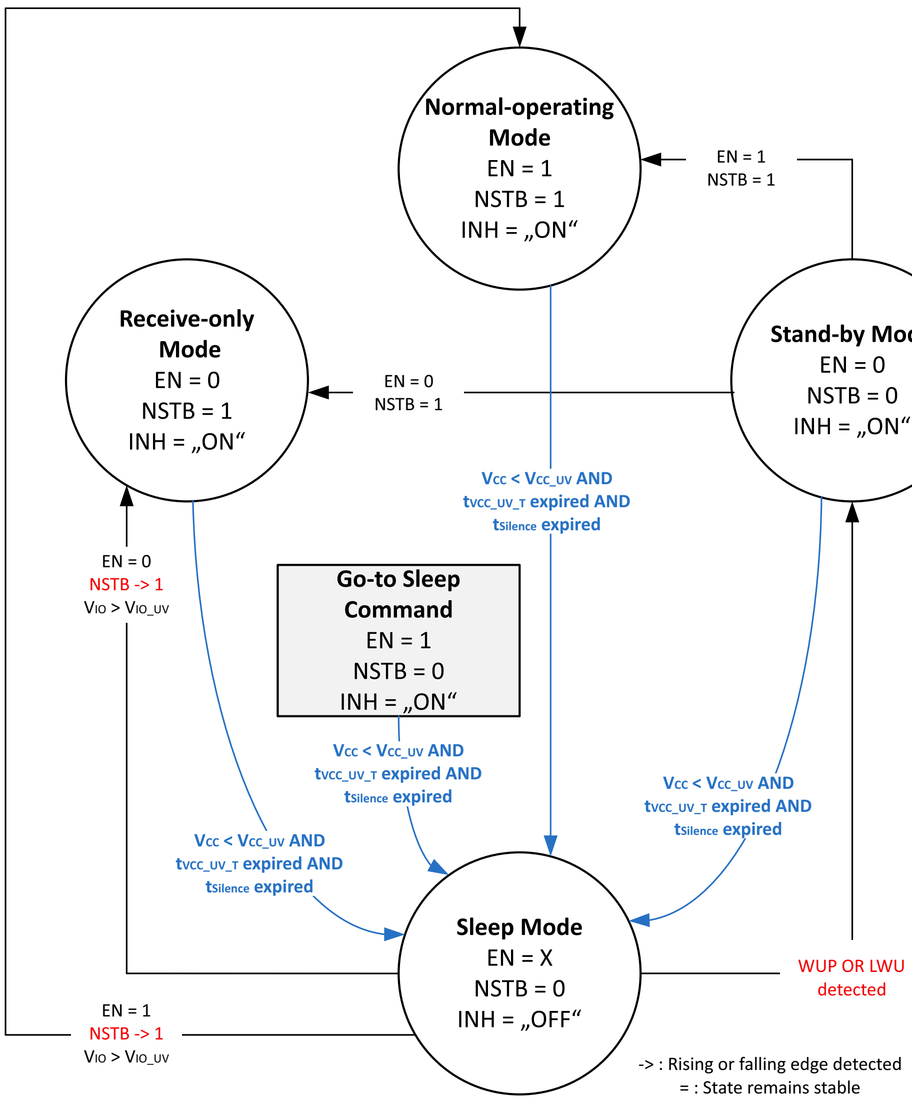


Figure 40 Possible Mode transitions due to V_{CC} undervoltage and mode pins

8.1.3 V_{IO} undervoltage detection

The V_{IO} supply undervoltage detection is active in all modes of operation. If a $V_{IO} < V_{IO\_UV}$ undervoltage event is detected, the mode control input pins EN and NSTB are blocked. Due to the internal pull-down current sources the TLE9252V enters then Stand-by Mode in order to reduce the current consumption. If $V_{IO} < V_{IO\_UV}$ for $t > t_{VIO\_UV\_T}$ AND $t_{Silence}$ timer has expired (no bus communication is monitored), the device will go to Sleep Mode (INH switched off) in order to minimize the current consumption.

8.2 TxD Dominant Time-out Detection

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. 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. This failure may occur for example due to TxD pin shorted to ground. For detailed explanation and example measurements please refer to TLE9252V Diagnostics via NERR Application Note.

8.3 RxD Recessive Clamping detection

The RxD Recessive Clamping detection is only active 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. The microcontroller can then transmit a message to the 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. Therefore TLE9252V detects this failure on RxD pin and the transmitter is disabled immediately, so that the corrupted, non-synchronized node is prevented from disturbing the remaining bus traffic. The RxD Recessive Clamping is indicated by setting the NERR pin to "low" in Normal-operating Mode. The TLE9252VSK releases the failure flag and the transmitter output stage if the RxD clamping failure disappears. For detailed explanation and example measurements please refer to TLE9252V Diagnostics via NERR Application Note.

8.4 Short Circuit Scenario

Figure 41 shows short circuit types on the HS CAN bus. The CANH and CANL pins are short circuit proof to GND and to supply voltage. A current limiting circuit protects the transceiver from damage. If the device heats up due to a permanent short at CANH or CANL, then the overtemperature protection switches off the transmitter.

Depending on the type of short circuit on CANH and CANL, communication might be still possible. If only CANL is shorted to GND or only CANH is shorted to V_{BAT}, then dominant and recessive states may be recognized by the receiver. Timings and/or differential output voltages might be not valid according to ISO11898 but still in the range for the receiver working properly.

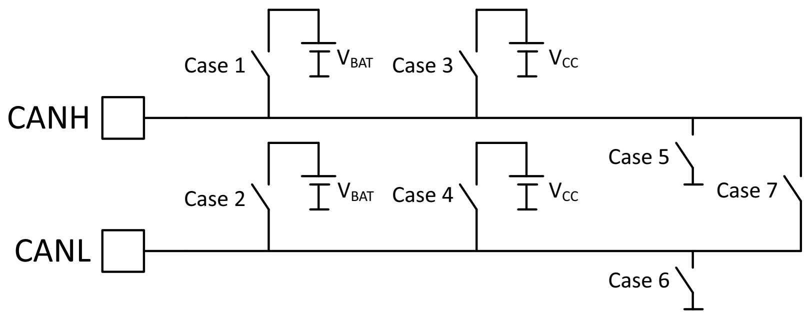


Figure 41 HS CAN Bus Short Circuit Types

Communication on the HS CAN bus is blocked in the following cases:

- CANH and CANL shorted (Case7)
- CANH shorted to GND (Case 5)
- CANL shorted to V_{BAT} (Case 2) or V_{CC} (Case 4)

If a short circuit occurs, then the V_{CC} supply current for the transceiver can increase significantly. It is recommended to dimension the voltage regulator for the worst case, especially when V_{CC} also supplies the microcontroller. V_{CC} supply current increases in dominant state. The recessive current remains unchanged.

CANH shorted to GND

The datasheet specifies a maximum short circuit current of 100mA. When transmitting a dominant state to the bus, 5V is shorted to GND through the transmitter output stage. Power dissipation with 10% duty cycle (DCD) is:

P = DCD x U x I = 0.1 x 5V x 100mA = 0.05W.

The average fault current with worst case parameters and assuming a realistic duty cycle of 10% is:

$I_{CC,Fault} = I_{CC,rec} \times 0.9 + I_{CANH,SC} \times 0.1 =$ 13.6mA.

CANL shorted to V_{BAT}

If CANL is shorted to V_{BAT}, then the current through the CANL output stage is even higher and the device heats up faster. The datasheet specifies a maximum short circuit current of 100mA. When transmitting a dominant state to the bus, V_{BAT} is shorted to GND through the transmitter output stage. Assuming a realistic duty cycle of 10% for this case and the power dissipation is:

P = DCD x U x I = 0.1 x V_{BAT} x 100mA = 0.1 x 18V x 100mA = 0.18W.

CANH shorted to V_{BAT}

Short circuit of CANH to V_{BAT} can result in a permanent dominant state on the HS CAN bus, due to the voltage drop at the termination resistors of the network. Therefore the termination resistor has to be chosen accordingly. If a short circuit of CANH to V_{BAT} occurs, then the power loss in the termination resistor must be taken into account. **Figure 42** shows the current in case CANH is shorted to V_{BAT}. When transmitting a dominant state to the bus, the current flows through the termination resistor and CANL to GND. Power loss in the termination resistor and CANL assuming a battery voltage of 18 V and a duty cycle of 10% is:

$P_{Loss\_Termination}$ = 0.1 x ($R_{Termination}$ x $I_{CANL,SC}$)x $I_{CANL,SC}$= (60Ω x 100mA) x 100mA = 0.6W

P_{Loss_CANL} = 0.1 x (V_{BAT} - ($R_{Termination}$ x $I_{CANL,SC}$)) x $I_{CANL,SC}$)= 0.1 x (18V-6V) x 100mA = 0.1 x 12V x 100mA = 0.12W

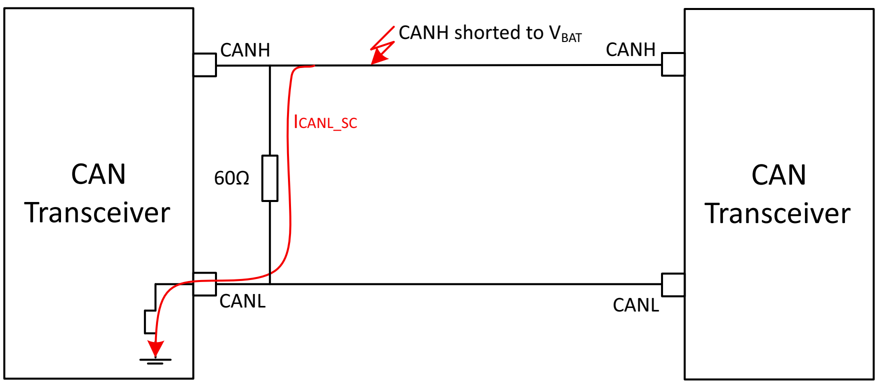


Figure 42 Current Flowing in Case of a Short Circuit CANH to V_{BAT}

8.5 TLE9252V Junction Temperature

In Normal-operating mode highest power dissipation occurs with 50% duty cycle (D) at an ambient temperature of 150 °C:

$P_{NM,MAX} = D \times (I_{CC\_R} \times V_{CC,max}) + D \times (I_{CC\_D} \text{ x } V_{CC,max}) + (I_{BAT} \times V_{BAT,max}) =$
$= 0.5 \times (4 \text{ mA} \times 5.5 \text{ V}) + 0.5 \text{ x } (60 \text{ mA} \times 5.5 \text{ V}) + (1.2\text{mA} \times 18 \text{ V}) = 197.6 \text{ mW}.$

Junction temperature increases due to power dissipation and depending on the package.

However, typical conditions are more like this: ambient temperature is below 150 °C, overall duty cycle is less than 50%, and supply voltages V_{CC} and V_{BAT} have their typical values instead of maximum values.

Power dissipation is much lower for such typical conditions:

$P_{NM,AVG} = D \times (I_{CC\_R,Typ} \times V_{CC,AVG}) + D \times (I_{CC\_D,Typ} \text{ x } V_{CC,AVG}) + (I_{BAT,Typ} \times V_{BAT,AVG}) =$
$= 0.9 \times (2 \text{ mA} \times 5 \text{ V}) + 0.1 \text{ x } (38 \text{ mA} \times 5 \text{ V}) + (850\mu\text{A} \times 13.5 \text{ V}) = 39.5 \text{ mW}.$

Table 10 Increase of Junction Temperature ΔT_j

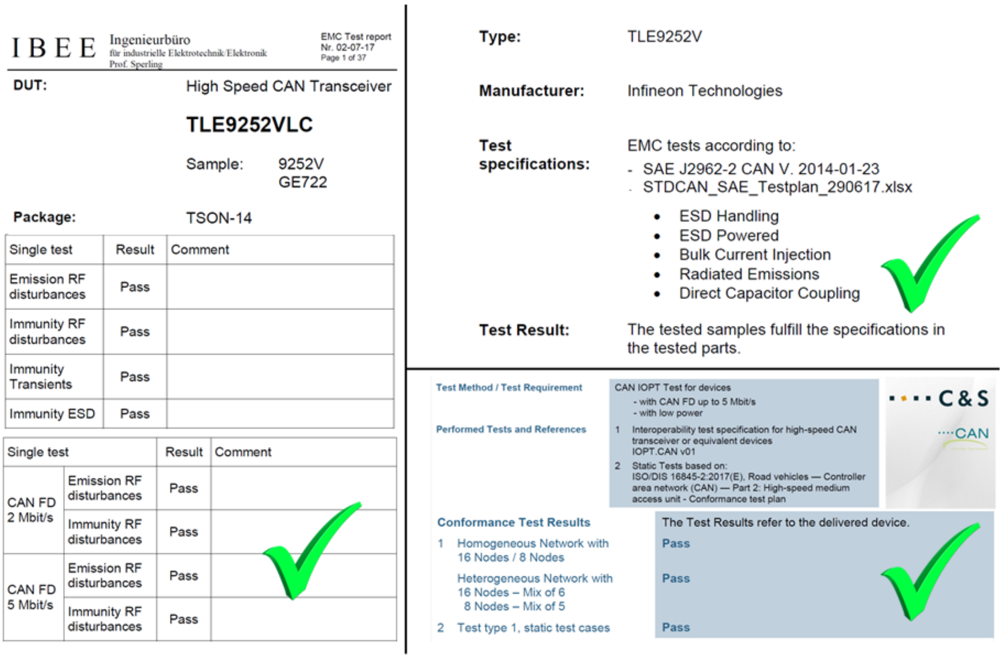
Package	R_{thja} in K/W	ΔT_j in K	Conditions
PG-DSO-14	140	27.6	$P_{NM,MAX}$ = 197.6 mW; T_{amb} = 150 °C; 50% duty cycle; $V_{CC} = V_{CC,max}$; $V_{IO} = V_{IO,max}$
PG-DSO-14	140	5.5	$P_{NM,AVG}$ = 39.5 mW; T_{amb} = 85 °C; 10% duty cycle; $V_{CC} = V_{CC,typ}$; $V_{IO} = V_{IO,typ}$
PG-DSO-14	140	6	Short Circuit CANH to GND 10% duty cycle;
PG-DSO-14	140	21.6	Short Circuit CANL to V_{BAT} 10% duty cycle;

If a short circuit occurs, then the TLE9252V heats up. The higher the duty cycle, the higher the power dissipation and thermal shutdown can occur due to high temperature. The receiver is still enabled with only the transmitter disabled. The behavior is identical to Receive-only mode.

9 TLE9252V Certificates

For OEM approval it is very important to receive certain certificates. These certificates show evidence for ISO11898-2: 2016 compliancy and also passing stringent EMC requirements according to IEC62228-3 and SAE J2962-2 specification. TLE9252V has received following certificates:

- C&S Conformance Test
- IBEE Zwickau EMC Test according to IEC62228-3
- SAE J2962-2 EMC Test



IBEE Ingenieurbüro für industrielle Elektrotechnik/Elektronik Prof. Sperling — EMC Test report Nr. 02-07-17 Page 1 of 37

DUT: High Speed CAN Transceiver **TLE9252VLC**

Sample: 9252V GE722

Package: TSON-14

Single test	Result	Comment
Emission RF disturbances	Pass	
Immunity RF disturbances	Pass	
Immunity Transients	Pass	
Immunity ESD	Pass	

Single test		Result	Comment
CAN FD 2 Mbit/s	Emission RF disturbances	Pass	
	Immunity RF disturbances	Pass	
CAN FD 5 Mbit/s	Emission RF disturbances	Pass	
	Immunity RF disturbances	Pass	

Type: TLE9252V

Manufacturer: Infineon Technologies

Test specifications: EMC tests according to:
- SAE J2962-2 CAN V. 2014-01-23
- STDCAN_SAE_Testplan_290617.xlsx
  - ESD Handling
  - ESD Powered
  - Bulk Current Injection
  - Radiated Emissions
  - Direct Capacitor Coupling

Test Result: The tested samples fulfill the specifications in the tested parts.

C&S CAN

Test Method / Test Requirement: CAN IOPT Test for devices
- with CAN FD up to 5 Mbit/s
- with low power

Performed Tests and References:
1 Interoperability test specification for high-speed CAN transceiver or equivalent devices IOPT.CAN v01
2 Static Tests based on: ISO/DIS 16845-2:2017(E), Road vehicles — Controller area network (CAN) — Part 2: High-speed medium access unit - Conformance test plan

Conformance Test Results — The Test Results refer to the delivered device.
1 Homogeneous Network with 16 Nodes / 8 Nodes — Pass
Heterogeneous Network with 16 Nodes – Mix of 6, 8 Nodes – Mix of 5 — Pass
2 Test type 1, static test cases — Pass

Figure 43 Overview of received Certificates

Terms and Abbreviations

Table 11 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

10 Revision History

Revision	Date	Changes
1.02	2018-07-12	Application Note updated: • Added descirption for TLE6251-2G pin-out compatibility in **Chapter 1.3**.
1.01	2018-01-19	Application Note updated: • Corrected description in **Chapter 5.5**: The Local wake-up detection is enabled if $V_{BAT} > V_{BAT\_UV}$. • Corrected description in **Chapter 4.11**: $(R_{VBAT\_WAKE} + R_S) * I_{Pull,max} < 0.35 * V_{BAT\_min}$
1.0	2017-11-27	Application Note created

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