TLE9250Vxx

Z8F57889424

Family overview   Support

Preface

Scope and purpose

This document provides application information for the transceiver TLE9250Vxx from Infineon Technologies AG as physical medium attachment within a Controller Area Network (CAN).

This document contains information about:

- Detailed TLE9250Vxx pin description, see ***Pin description***
- Power supply concepts, see ***Transceiver supply***
- Current consumption aspects, see ***Current consumption***
- Mode control hints, see ***Mode control***
- Quiescent current savings, see ***Mode control***

This document refers to the datasheet of the Infineon Technologies AG CAN transceiver TLE9250Vxx.

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.

For further information or further support please refer to ***Infineon Support Webpage***.

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1 Pin description

1.1 V_{IO} pin

The V_{IO} pin is needed for the operation with a microcontroller to match the voltage level between microcontroller and transceiver. It can also be used to decouple microcontroller and transmitter supply. Place a 100 nF capacitor directly at theV_{IO} pin to ground.

Benefits of using the V_{IO} pin:

- Improved EMC performance
- Transmitter supply V_{CC} can be switched off separately

The digital reference supply voltage V_{IO} has two functions:

- Supply of the internal logic of the transceiver (state machine)
- Supply of the normal receiver, see ***Pretended Networking usage (benefit of forced receive-only mode)***
- Voltage adaption for external microcontroller (3.0 V < V_{IO} < 5.5 V)

As long as V_{IO} is supplied ($V_{IO} > V_{IO\_UV}$) the state machine of the transceiver supports mode changes. If a microcontroller uses $V_{CC} \neq 5$ V, then the V_{IO} pin must be connected to the power supply of the microcontroller. Due to the V_{IO} pin feature the TLE9250Vxx can work with various microcontroller supplies. If V_{IO} is available, then both transceiver and microcontroller are fully functional. Below $V_{IO} < V_{IO\_UV}$ the TLE9250Vxx is in power on reset. To enter the normal-operating mode $V_{IO} \geq V_{IO\_UV}$ is required.

1.2 V_{CC} pin

The V_{CC} pin supplies the transmitter output stage. Place a 100 nF capacitor directly at V_{CC} pin to ground.

Table 1 Transmitter state depending on V_{CC}

V_{CC}	Transmitter state	Note
$V_{CC} < V_{CC\_UV}$	Disabled	3.8 V < V_{CC_UV} < 4.3 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	–
5.5 V < V_{CC} < 6 V	Enabled; parameters may be outside the specified range	–
V_{CC} > 6 V	Damage of TLE9250Vxx possible	–

1.3 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. Use the same GND for transceiver, microcontroller and the HS CAN bus system.

1.4 RxD pin

RxD is an output pin. In normal-operating mode the device displays the data stream received from the HS CAN bus on the RxD output pin. Do not use a series resistor within the RxD line between transceiver and microcontroller. A series resistor may add delay, which has impact on the timing symmetry and delay timings, especially in high data rate applications with CAN FD.

1.5 TxD pin

TxD is an input pin. The TxD pin receives the data stream from the microcontroller. If in normal-operating mode $V_{IO} > V_{IO\_UV}$, the device transmits the data stream 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 TxD input pin has an integrated pull-up resistor to V_{IO}. If TxD is permanently "low", for example due to a short circuit to GND, then the TxD time-out feature blocks the signal on the TxD input pin. Do not use a series resistor within the TxD line between transceiver and microcontroller. A series resistor may add delay, which degrades the performance of the transceiver, especially in high data rate applications.

1.6 NEN pin

The NEN pin sets the mode of TLE9250Vxx and is usually directly connected to an output port of a microcontroller. For a disconnected NEN pin or microcontroller ports in tristate the TLE9250Vxx has an integrated pull-up resistor to V_{IO}. The device is in power-save mode by default in order to enable low current consumption. This reduces disturbance to the HS CAN bus. ***Table 2*** shows mode changes via the NEN pin, assuming $V_{IO} > V_{IO\_UV}$. ***Table 2*** on page 4 describes features and modes of operation.

Table 2 Mode selection via NEN

Mode of operation	NEN	V_{CC}	Note	Receiver	Transmitter
Power-save mode	"high"	"X"[1)	–	Disabled	Disabled
Normal-operating mode	"low"	$> V_{CC\_UV}$	–	Enabled	Enabled

The power-save mode is the low-power mode of TLE9250Vxx. In this mode both the transmitter and the receiver are disabled and current consumption is reduced. The user can deactivate transmitter of TLE9250Vxx either by setting the NEN pin to "low" or by switching off V_{CC}. This can be used to implement two different fail safe paths in case a failure is detected in the ECU.

1.7 CANH and CANL pins

CANH and CANL are the CAN bus input and output pins. The TLE9250Vxx 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

To achieve optimum electromagnetic emission performance, transitions from dominant to recessive and from recessive to dominant are performed as smooth as possible also at high data rate. Due to the excellent ESD robustness on CANH and CANL no external ESD components are necessary to fulfill OEM requirements.

ESD robustness:

- HBM (Human Body Model): ±8 kV
- IEC 61000-4-2 Gun Test: ±11 kV, see EMC Test Report Nr. 01-07-2017 and Nr. 06-08-2017

1 "X": not relevant.

2 Transceiver supply

The V_{IO} pin supplies the internal logic of the TLE9250Vxx. The V_{CC} pin 5 V supply is used to create the CANH and CANL signal. The V_{CC} pin supplies the transmitter output stage as well. The V_{IO} pin supplies the receiver. This chapter describes aspects of power consumption and voltage supply concepts of TLE9250Vxx.

2.1 Voltage regulator

It is recommended to use one of the following Infineon low drop output voltage regulators:

- 3.3 V V_{IO} power supply: TLS850D0TAV33 (500 mA), TLS850F0TAV33 (500 mA), TLS810B1LDV33 (100 mA), ***TLE4266-2GS V33*** (150 mA),
- 5 V V_{IO} and V_{CC} power supply: TLS850D0TAV50 (500 mA), ***TLS850F0TA V50*** (500 mA), ***TLS810D1EJ V50*** (100 mA), ***TLS810B1LD V50*** (100 mA), ***TLE4266-2*** (150 mA)
- 3.3 V and 5 V dual voltage power supply: ***TLE4476D***
- Dual 5 V voltage power supply: ***TLE4473G V55***

Refer to ***Infineon Linear Voltage Regulators*** for voltage regulator portfolio, data sheets and app notes.

2.2 External circuitry on V_{CC} and V_{IO}

In order to reduce electromagnetic emission and to improve the stability of the input voltage level on V_{CC} and V_{IO} of the transceiver, it is recommended to place capacitors on the PCB. During sending a dominant bit to the HS CAN bus, the current consumption of TLE9250Vxx is higher than during sending a recessive bit. Data transmission changes the load profile on V_{CC}, which may reduce the load regulation of V_{CC}. If several CAN transceivers are connected in parallel and are supplied by the same V_{CC} and/or V_{IO} power supply, for example from a LDO, then the impact on the load regulation of V_{CC} is even stronger. It is required to place a 100 nF capacitor directly at V_{CC} and V_{IO} pin to ground. Without 100 nF decoupling capacitance higher electromagnetic emission has to be expected. Ceramic capacitors are recommended due to their low ESR. The output of the V_{CC} and V_{IO} power supply has to be stabilized by a capacitor in the range of 1 to 50 µF, depending on the load profile.

2.3 Power-up sequence for V_{IO} and V_{CC}

As the TLE9250Vxx has V_{CC} and V_{IO} supply pin, this chapter describes possible scenarios for powering up the device. V_{CC} supplies the transmitter output stage while V_{IO} supplies the internal state machine of the TLE9250Vxx. There is no limitation for the start-up sequence for TLE9250Vxx:

- Scenario 1: If V_{IO} is supplied first, the internal state machine starts working for $V_{IO} > V_{IO\_UV}$. Then the mode of operation can be changed by the mode selection pin NEN. The transmitter of the TLE9250Vxx 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, then only the transmitter output stage is supplied. But as V_{IO} is not yet supplied, the output of the transmitter is high impedance (disabled, in order to not disturb the bus communication).
- Scenario 3: If V_{CC} and V_{IO} are connected to the same supply voltage (V_{supply} = 5 V), then the state machine starts working for $V_{Supply} > V_{IO\_UV}$ (max. 3.0 V) and the transmitter is enabled if $V_{Supply} > V_{CC\_UV}$ (max. 4.5 V).

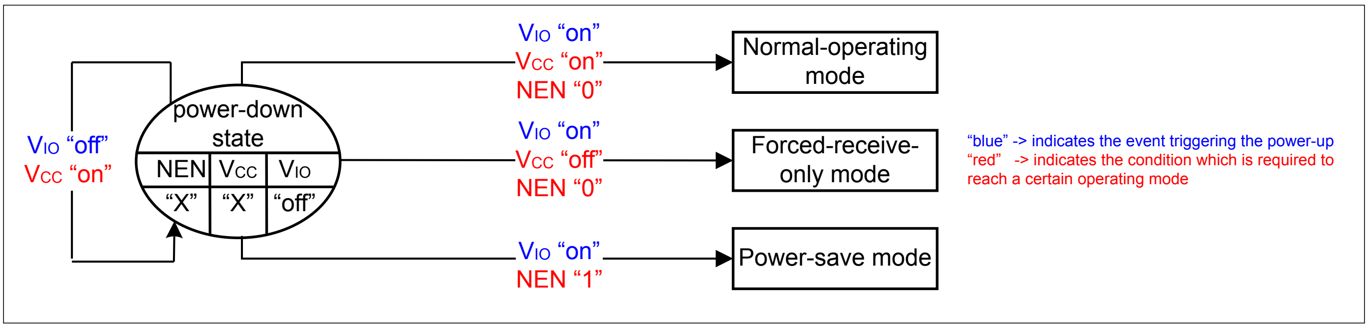

Figure 1 **Power-up scenarios for TLE9250Vxx**

2.4 V_{IO} feature

The TLE9250Vxx 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 of the TLE9250Vxx. Depending on the voltage supply of the microcontroller, the TLE9250Vxx can operate with the V_{IO} reference voltage input within the voltage range from 3.0 V to 5.5 V. The V_{CC} pin supplies the transmitter of the TLE9250Vxx. Therefore the V_{CC} supply input pin must be connected to a 5 V voltage regulator. Competitor devices use V_{CC} to supply the internal logic and the transmitter output stage and V_{IO} as a simple level shifter. Infineon's HS CAN transceivers can work in V_{CC} undervoltage condition or even with V_{CC} completely switched off in order to reduce quiescent current, see , ***Pretended Networking usage (benefit of forced receive-only mode)***.

2.4.1 V_{IO} (3.3 V) power supply concept

In order to reduce the power consumption of ECUs, the microcontroller might not be supplied by V_{CC} but by a lower voltage, for example 3.3 V. Therefore the TLE9250Vxx offers a V_{IO} supply pin, which is a voltage reference input in order to adjust the voltage levels on the digital input and output pins to the voltage supply of the microcontroller. With the V_{IO} reference voltage input the TLE9250Vxx can operate from 3.0 V to 5.5 V. If the microcontroller uses V_{CC} = 5 V supply, then V_{IO} supply must be connected to V_{CC} supply. The V_{IO} input must be connected to the supply voltage of the microcontroller, see ***Figure 2***.

In order to decouple the microcontroller and the HS CAN bus from each other with respect to noise and disturbances, it is possible to use a dual 5 V voltage regulator like ***TLE4473G V55***. In this case two independent 5 V LDOs supply V_{IO} and V_{CC}. This power supply concept improves EMC behavior and reduces noise.

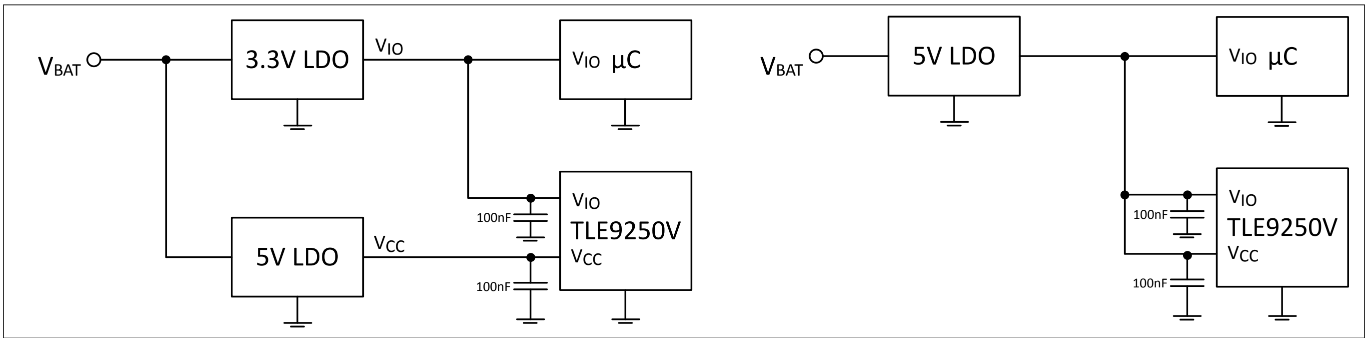

Figure 2 **3.3 V and 5 V power supply concept**

2.5 Current consumption

Current consumption depends on the mode of operation.

Normal-operating mode

Maximum current consumption of TLE9250Vxx on the V_{CC} supply is specified as 60 mA in dominant state and 4 mA in recessive state. Maximum current consumption of TLE9250Vxx on the V_{IO} supply is specified as 1.5 mA. To estimate theoretical current consumption in normal-operating mode, a duty cycle of 50% can be assumed, with fully loaded bus communication of 50% dominant state and 50% recessive state. In normal-operating mode the TLE9250Vxx consumes worst case maximum:

$$I_{CC\_AVG} = \frac{I_{CC\_REC} + I_{CC\_DOM}}{2} + I_{IO} = 32.75\ \text{mA}$$

Equation 1

Typically the current consumption is less than 15 mA.

Power-save mode and forced-power-save mode

In power-save mode most of the functions are turned off. V_{CC} can be switched off. The maximum current consumption is specified as 15 µA.

2.6 Loss of battery (transceiver unsupplied)

When TLE9250Vxx is unsupplied, CANH and CANL act as high impedance. The leakage current $I_{CANH,lk}$, $I_{CANL,lk}$ at CANH pin or CANL pin is limited to ±5 µA in worst case. When unsupplied, theTLE9250Vxx behaves like a 1 MΩ resistor towards the bus. Therefore the device perfectly fits applications that use both clamp 15 and clamp 30.

2.7 Loss of ground

If loss of ground occurs, the transceiver is unsupplied and behaves like in unpowered state. In applications with inductive load connected to the same GND, for example a motor, loss of ground can damage the transceiver. Excessive current can flow through the CAN transceiver when the inductor demagnetizes after loss of ground. The ESD structure of the transceiver cannot withstand that kind of electrical overstress (EOS). In order to protect the transceiver and other components of the module, an inductive load must be equipped with a free wheeling diode.

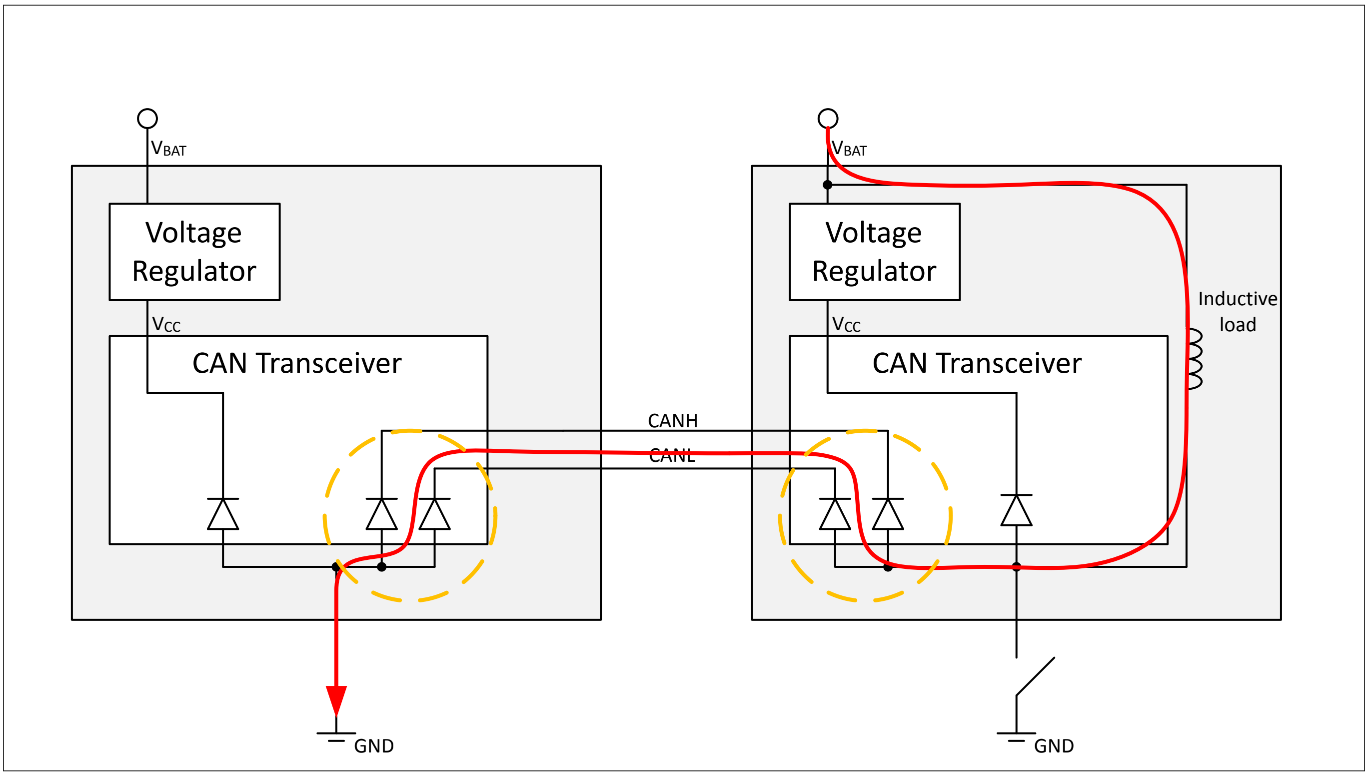

Figure 3 **Loss of ground with inductive load**

2.8 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 difference voltage (CAN_H - CAN_L) is relevant for the receiver. ***Figure 4*** shows a typical CAN signal with a DC ground shift of +2V.

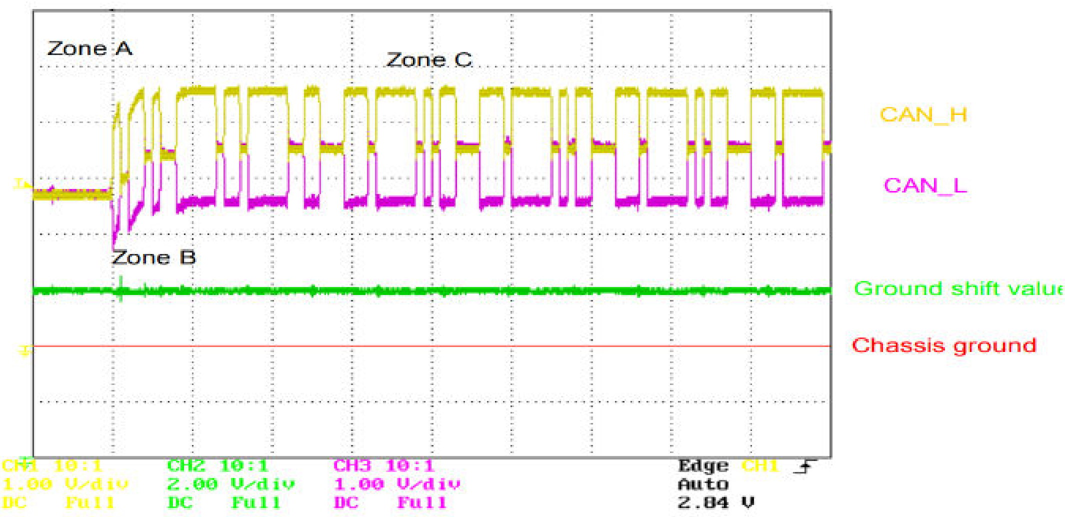

Figure 4 **DC ground shift signal**

Zone A : Shows the recessive voltage of the system, close to the nominal recessive value of 2.5 V. Zone B : When the transmitter starts to communicate the signal rises 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:

$$V_{rec} = \frac{V_{rec\_1} + V_{Shift\_1} + V_{rec\_2} + V_{Shift\_2} + V_{rec\_3} + V_{Shift\_3} + ... + ... + V_{rec\_n} + V_{Shift\_n}}{n}$$

Equation 2

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

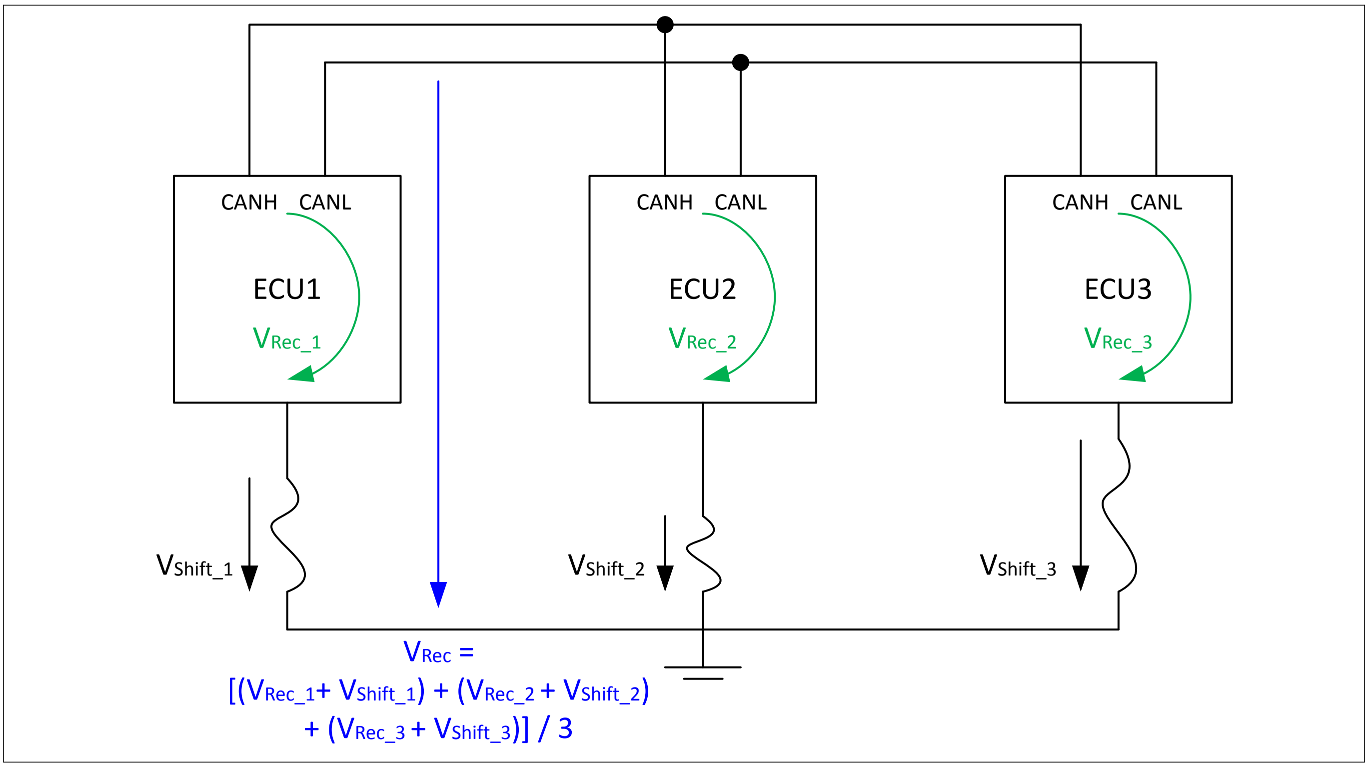

Figure 5 **Ground shift on three nodes (system view)**

3 Mode control

The modes of the TLE9250Vxx are controlled by the pin NEN and by the transmitter voltage V_{CC}.

3.1 Mode change by NEN

The mode selection pin NEN sets the mode of operation.

The TLE9250Vxx is in power-save mode independent of the status of V_{CC}. In order to change the mode to normal-operating mode, NEN must be switched to "low" and V_{CC} must be available.

3.2 Mode change delay

The HS CAN transceiver TLE9250Vxx 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. During the mode change from power-save mode to a non-low power mode the receiver and transmitter is enabled,. During the period t_{Mode} the RxD output pin is set to "high" and does not reflect the status on the CANH and CANL input pins. In addition, during t_{Mode}, the TxD path is blocked as well. When the mode change is completed, the TLE9250Vxx releases the RxD output pin. ***Figure 6*** shows this scenario.

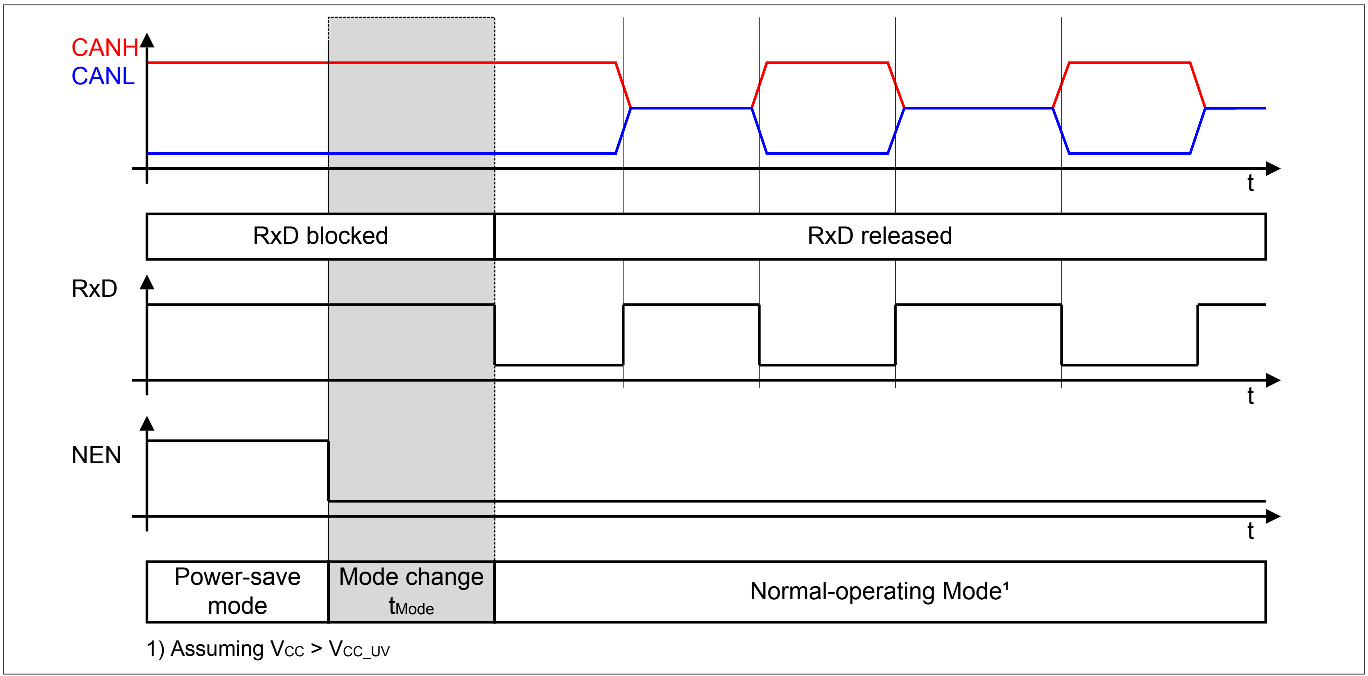

Figure 6 RxD behavior during mode change

The RxD output pin is not blocked nor set to "high" during the following mode changes:

- Normal-operating mode → forced receive-only mode
- Forced receive-only mode → normal-operating mode

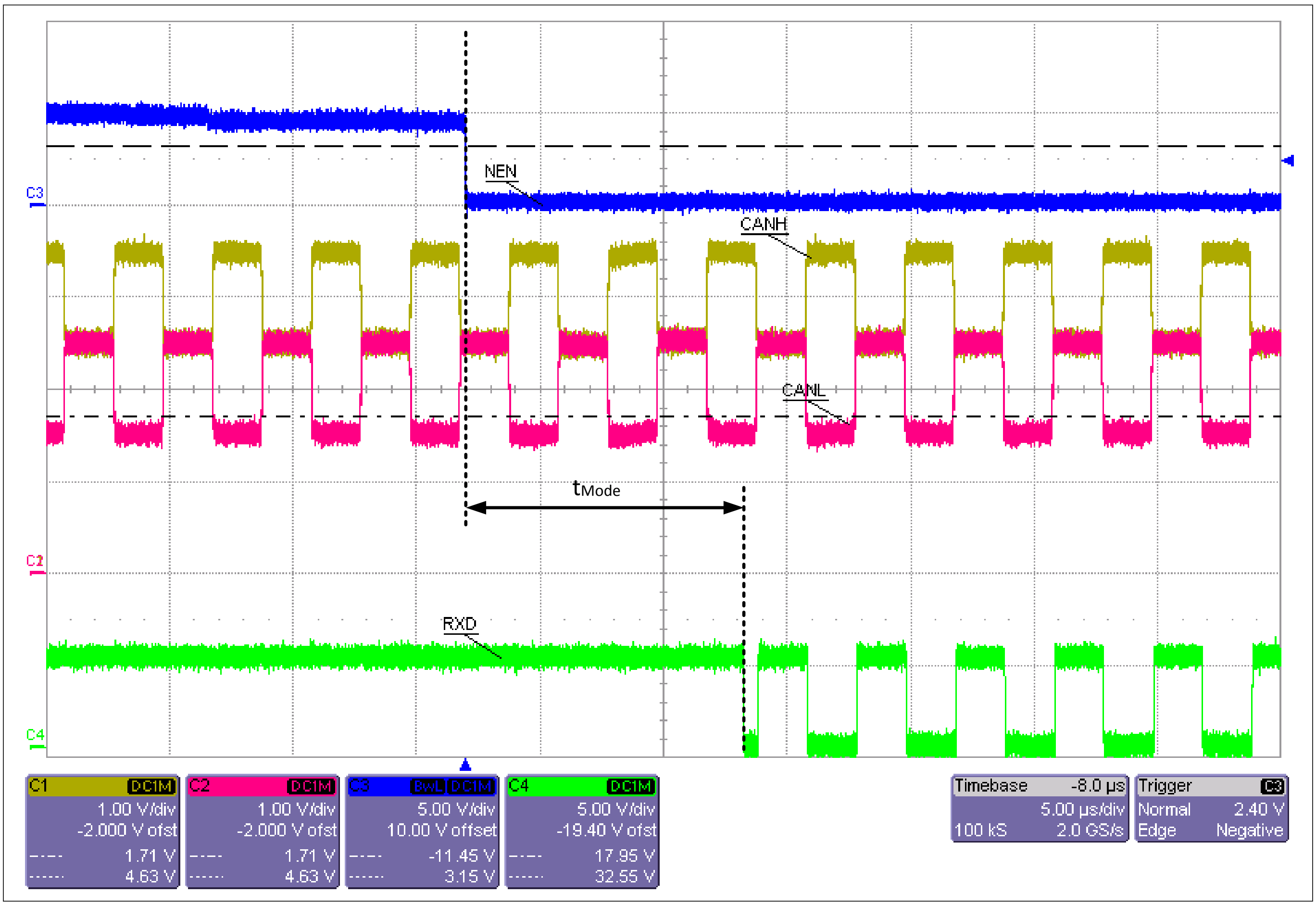

Figure 7 **Communication on the CAN bus: RxD behavior during mode change (power-save mode to normal-operating mode)**

In low-power mode the bus biasing is connected to GND. In normal-operating mode the bus biasing is connected to $V_{CC}/2$. When changing the mode of operation from low-power mode to normal-operating mode the bus biasing is changed from GND to $V_{CC}/2$. ***Figure 8*** shows an example measurement in a network when the bus biasing is enabled.

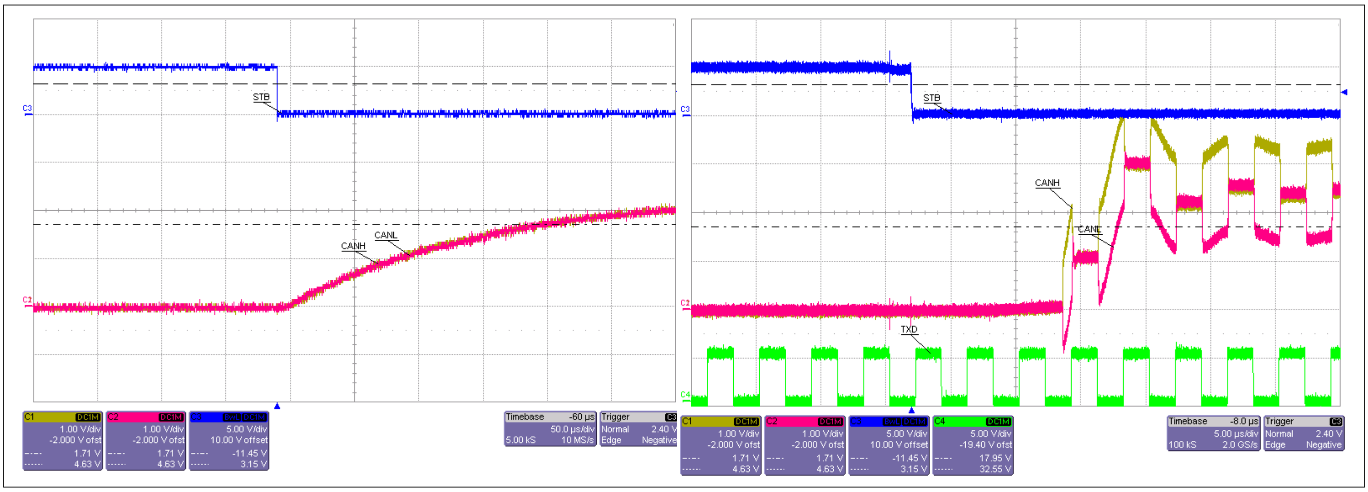

Figure 8 **Mode change low-power mode to normal-operating mode: bus biasing enabled**

3.3 Mode change due to V_{CC} undervoltage

A mode change due to V_{CC} undervoltage is only possible in normal-operating mode. If V_{CC} undervoltage persists longer than $t_{Delay(UV)}$, the TLE9250Vxx changes from normal-operating mode to . As soon as the TLE9250Vxx detects undervoltage, it disables the transmitter output stage so that no faulty data is sent to the HS CAN bus.

During $V_{CC} < V_{CC(UV)}$ fault condition, the TLE9250Vxx is set to forced receive-only mode and the TLE9250Vxx behaves as in receive-only mode. The receiver is enabled and converts the signals from the bus to a serial data stream on the RxD output pin.

If V_{CC} recovers, then $V_{CC} > V_{CC\_UV}$ triggers a mode change back to normal-operating mode.

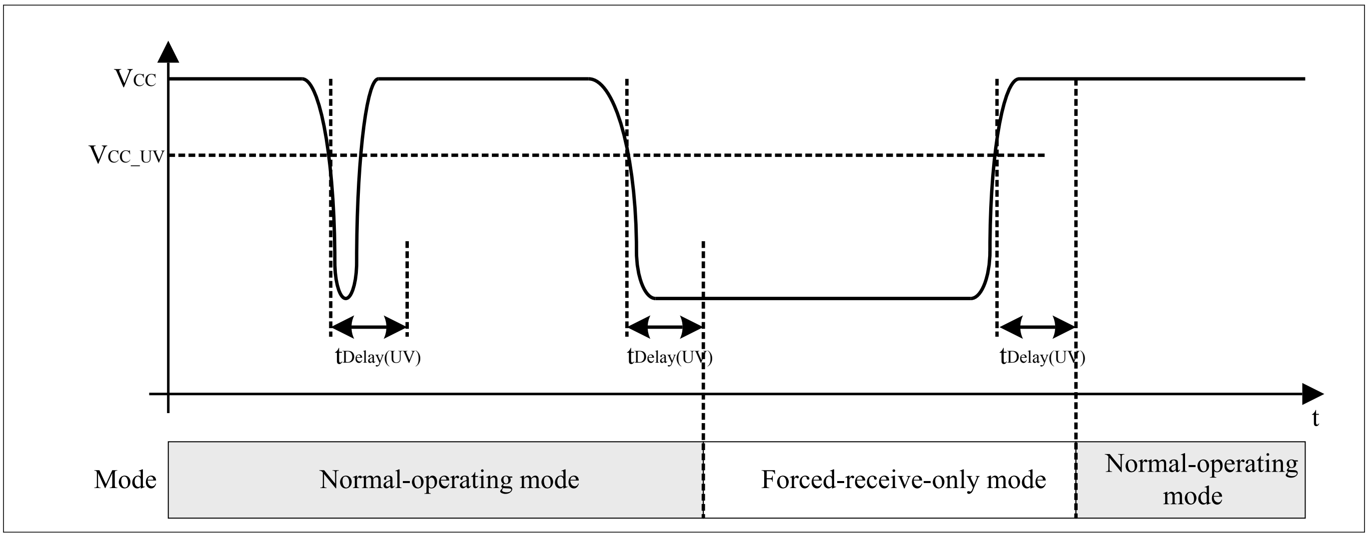

Figure 9 **V_{CC} undervoltage and recovery**

3.4 Pretended Networking usage (benefit of forced receive-only mode)

Infineon's HS CAN transceivers use the V_{IO} pin to supply the internal logic of the transceiver. The transmitter of the TLE9250Vxx is supplied by V_{CC} (typically = 5 V). This enables the TLE9250Vxx to support the forced receive-only mode, which is similar to the receive-only mode. Even if $V_{CC} < V_{CC(UV)}$ due to a fault condition, such as undervoltage or short circuit of V_{CC} to GND, or if V_{CC} is completely switched off, the receiver is enabled and provides data from the CAN bus to the RxD pin. This means the microcontroller can still receive all data sent to the CAN bus by other ECUs in CAN FD at up to 5 Mbit/s.

The microcontroller can control the V_{CC} voltage regulator. In order to set the TLE9250Vxx to forced receive-only mode, the microcontroller switches off the V_{CC} voltage regulator. Typical use cases for forced receive-only mode are:

- Pretended Networking:

  Most microcontrollers include power saving modes. Power saving modes set parts of the microcontroller to a low-power mode while other function blocks remain active. This mode is also known as stop mode. The V_{CC} LDO is switched off and the TLE9250Vxx is in forced receive-only mode. The CAN protocol handler of the microcontroller is enabled and monitors communication on the HS CAN bus. If the microcontroller detects a specific CAN message, the microcontroller exits the low power mode and switches on the V_{CC} LDO. After switching on the V_{CC} LDO, the TLE9250Vxx enters normal-operating mode and the ECU is fully functional and able to participate in the CAN communication. During vehicle operation, the aim is to reduce power consumption any time functions are not being used. Therefore Pretended Networking can be used to reduce current consumption of an ECU.
- Babbling idiot protection:

  If a CAN controller gets out of control and transmits unwanted messages to the bus, this will block other communication on the HS CAN bus. In forced receive-only mode the transmitter of the TLE9250Vxx is disabled, a potential babbling idiot stops transmitting and the CAN bus is released, allowing other CAN controllers to communicate. This is important for high system reliability of an application.
- During voltage transient on V_{CC} supply, when $V_{CC} < V_{CC\_UV}$, the normal receiver remains fully functional. If there is ongoing communication on the HS CAN bus, the receiving node can still receive messages (classical CAN and CAN FD) on the bus when $V_{CC} < V_{CC\_UV}$ and is not disconnected from communication. As a result during $V_{CC} < V_{CC\_UV}$ failure, less error messages will be sent out to the CAN bus, which enables more robust and reliable communication in the CAN bus network.

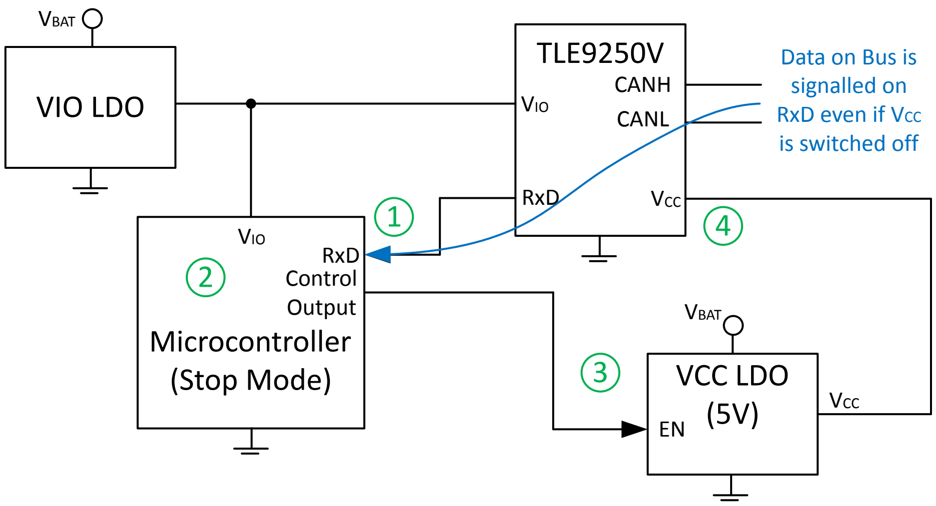

Figure 10 **Pretended Networking using forced receive-only mode**

Procedure for Pretended Networking:

1. The TLE9250Vxx is in forced receive-only mode. All messages on the bus are indicated on the RxD output.

2. The microcontroller is in stop mode. The CAN protocol handler is enabled. On detection of a dedicated valid CAN frame, the microcontroller exits the stop mode and ramps up to be fully functional.
3. The microcontroller switches on the V_{CC} LDO.
4. As soon as $V_{CC} > V_{CC\_UV}$, the TLE9250Vxx enters normal-operating mode and the ECU can participate in the CAN communication.

3.5 Transition from power-save mode to forced receive-only mode

From normal-operating mode the TLE9250Vxx enters forced receive-only mode on detecting V_{CC} undervoltage. However, in power-save mode V_{CC} undervoltage detection is disabled. With V_{CC} below the undervoltage threshold V_{CC_UV}TLE9250Vxx in power-save mode, when EN is switched from "high" to "low", the TLE9250Vxx changes to normal-operating mode. In normal-operating-mode V_{CC} undervoltage detection is enabled, and thus the undervoltage event is detected. This in turn triggers a mode change to forced receive-only mode. The overall transition time period from power-save mode to forced receive-only mode is $t < t_{Mode}$. During the mode change from power-save mode to forced receive-only mode the RxD output pin is permanently set to "high" and does not reflect the status of the CANH and CANL input pins. After the mode change to forced receive-only mode is completed, the TLE9250Vxx releases the RxD output pin.

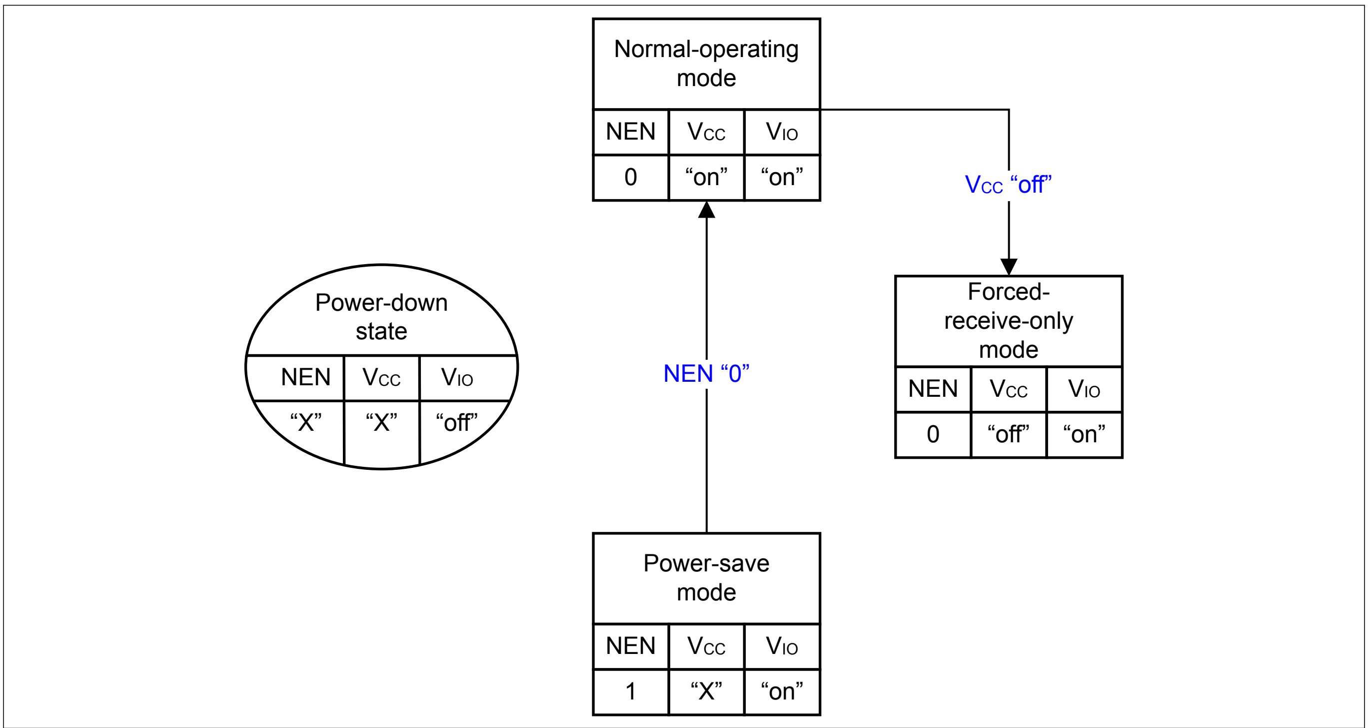

Figure 11 **Power-save mode to forced receive-only mode**

4 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

Revision history

Revision	Date	Changes
1.41	2021-02-17	Editorial changes
1.4	2020-07-27	Editorial changes
1.3	2019-03-26	• Editorial changes
1.2	2018-07-13	• Editorial changes
1.1	2018-01-15	Added description for pin behavior assessment: • V_{IO} short circuit to CANL • N.C. short circuit to GND, V_{CC}, CANL Changed description for RxD short circuit to V_{CC} and V_{IO} Rename pin FMEA to pin behavior assessment
1.0	2017-08-04	Document created

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