## APPLICATION Hints

# TJA1080
# FlexRay Transceiver

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**Philips**
**Semiconductors**

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## Abstract

The TJA1080 is an advanced transceiver device for applications up to 10Mbit/s in automotive high-speed time triggered communication systems such as FlexRay. It supports the differential bus signal representation described in the FlexRay Electrical Physical Layer Specification [2]. FlexRay is a new communication system developed by the FlexRay industry consortium and designed to meet the requirements for future X-by-Wire applications (e.g. steer-by-wire, brake-by-wire). It provides synchronous and asynchronous frame transfer, guaranteed frame latency times along with adjustable scalability.

The TJA1080 transceiver can not only be used in a bus node application, but it is also the key element for the design of an active star coupler. These application hints provide information on how to implement the FlexRay Physical Layer using the TJA1080 device.

# APPLICATION Hints

# TJA1080
# FlexRay Transceiver

## TR0417



Author:
Thomas Suermann

Philips Semiconductors
Automotive Innovation Center
Germany

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## Summary

This report is accompanying the TJA1080 data sheet [1] and provides information on how to implement the FlexRay electrical physical layer using the TJA1080 transceiver. The document describes in detail the application of the device as a node transceiver and as a star coupler transceiver. Main topics are hardware application, low-power management, wakeup mechanisms, supply voltage monitoring and reading of status and diagnosis information. It is assumed that the reader is familiar with the TJA1080 data sheet and the FlexRay communication system as specified in the FlexRay Protocol [4] and FlexRay Electrical Physical Layer Specification [2].

Note: The TJA1080 is currently still under development. These application hints refer to the targeted functionality of the later series silicon version. Technical issues related specifically to the first engineering samples are described in the appendix.



## Revision History

| Version | Remarks |
|---|---|
| 23.04.2004 | Initial Version |
| | |
| | |

# Contents

# 1. INTRODUCTION

The TJA1080 transceiver is optimized for use in time-triggered communication systems such as FlexRay. The media access scheme of FlexRay is based on a static time division multiple access (TDMA) scheme, which allows guaranteed response latency times. The FlexRay system provides the communication infrastructure needed for automotive “X-by-Wire” applications like “steer-by-wire” and “brake-by-wire” and other advanced high-speed automotive applications.

In node applications the TJA1080 provides the physical link between the FlexRay protocol controller and the FlexRay physical bus and is able to support data rates between 500kbit/s and 10Mbit/s. In addition, the TJA1080 provides functionality to build an active star coupler. Here, several TJA1080 devices are simply connected together. The active star coupler can be used advantageously to increase the total network length and to improve the error confinement behaviour of the communication network.

Another feature of FlexRay is the application of a bus guardian to supervise the access from the communication controller on the bus. The TJA1080 supports the use of a decentralized bus guardian by providing the necessary interface pins (BGE and RXEN).

The TJA1080 will be available in a SSOP20 package. Its pinning is shown in Figure 1-1.

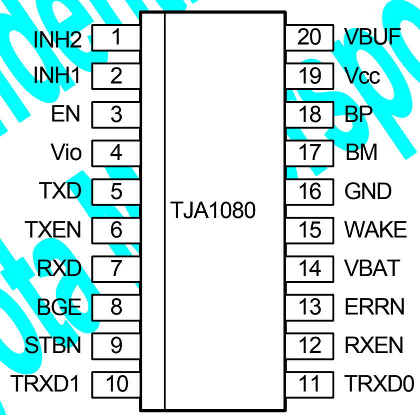


Figure 1-1: Pinning of TJA1080

# 2. INTRODUCTION TO FLEXRAY ELECTRICAL PHYSICAL LAYER

This chapter gives a brief overview on the main features of the FlexRay Physical Layer like electrical signaling, active star coupler, dual-channel application and bus access supervision.

## 2.1 Electrical Signaling

A FlexRay bus may assume four different bus states, denoted *Idle_LP*, *Idle*, *Data_1* and *Data_0*. A principle voltage level scheme is depicted in Figure 2-1. The bus wires are denoted BP and BM. The differential voltage on the bus is defined as uBus = uBP – uBM.

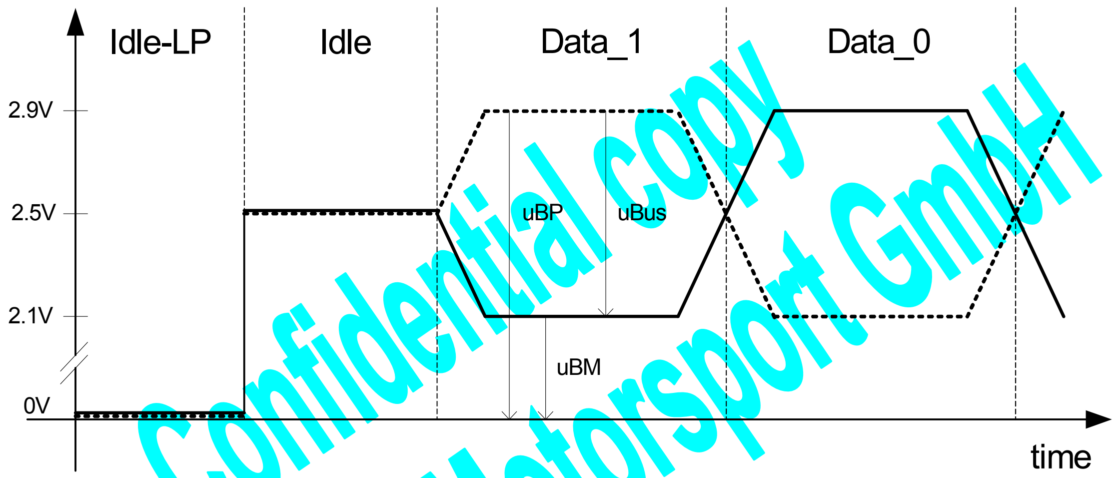


Figure 2-1: Electrical Signaling



A FlexRay bus receiver distinguishes only between the bus states *Idle*, *Data_1* and *Data_0*. *Idle* is reliably received when the differential bus voltage uBus is between –150mV and +150mV for longer than *dIdleDetection* [2].

*Data_1* is reliably received when the differential voltage uBus is above +300mV. *Data_0* is reliably received when the differential voltage uBus is below –300mV.

## 2.2 Active Star Coupler

FlexRay allows interconnecting nodes via a central active star coupler. The active star coupler has the function to transfer received messages from one branch to all other branches. Since the active star device has an own transmitter and receiver circuit for each branch, the branches are actually electrically decoupled from each other. This allows confining bus faults to the corrupted branch only. An example of an active star network is illustrated in Figure 2-2.

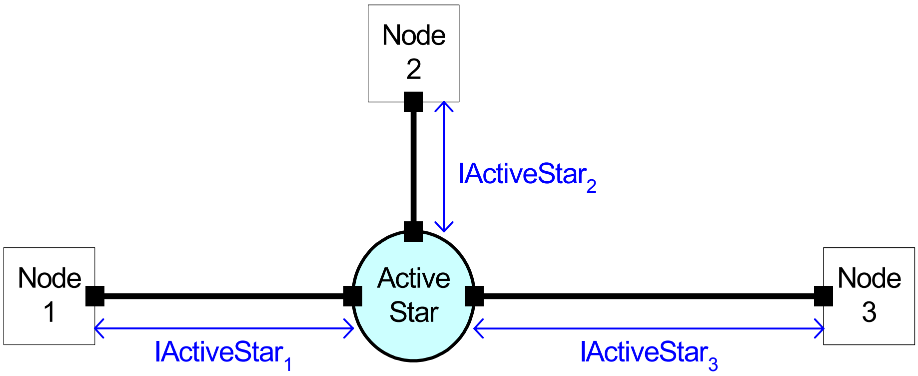


Figure 2-2: Active star network

## 2.3 Dual-channel Application

The FlexRay communication system supports up to two channels. That means a node may be connected to both channels simultaneously. This feature can be used to realize redundancy for safety- relevant applications or to increase communication bandwidth. A node can either be connected to both channels A and B, only to channel A or only to channel B.

## 2.4 Bus Access Supervision

A bus guardian protects the communication channel from improper transmissions by a faulty communication controller that attempts to transmit outside of its schedule. After being configured by the host, the bus guardian has independent knowledge of the node's communication schedule and restricts transmission to only those times allowed by the schedule. The bus guardian's BGE output signal defines the time during which the communication controller is allowed to access the bus. This signal enables the transmitter of the transceiver. Figure 2-3 describes how bus guardians are connected to a communication controller in a dual-channel FlexRay node.

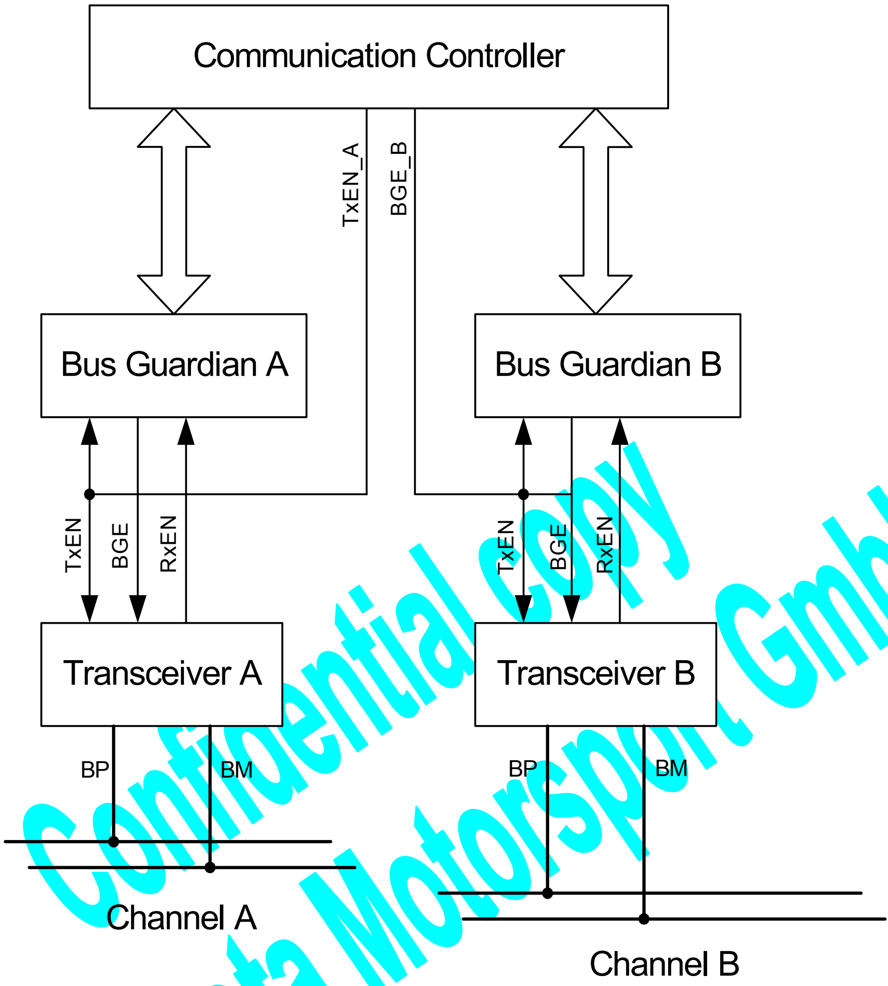


Figure 2-3: Bus access supervision with bus guardian

## 3. APPLICATION OF THE TJA1080 IN FLEXRAY SYSTEMS

The TJA1080 (also referred to as "1080") can be used either as a node transceiver or as a star transceiver as illustrated in Figure 3-1.

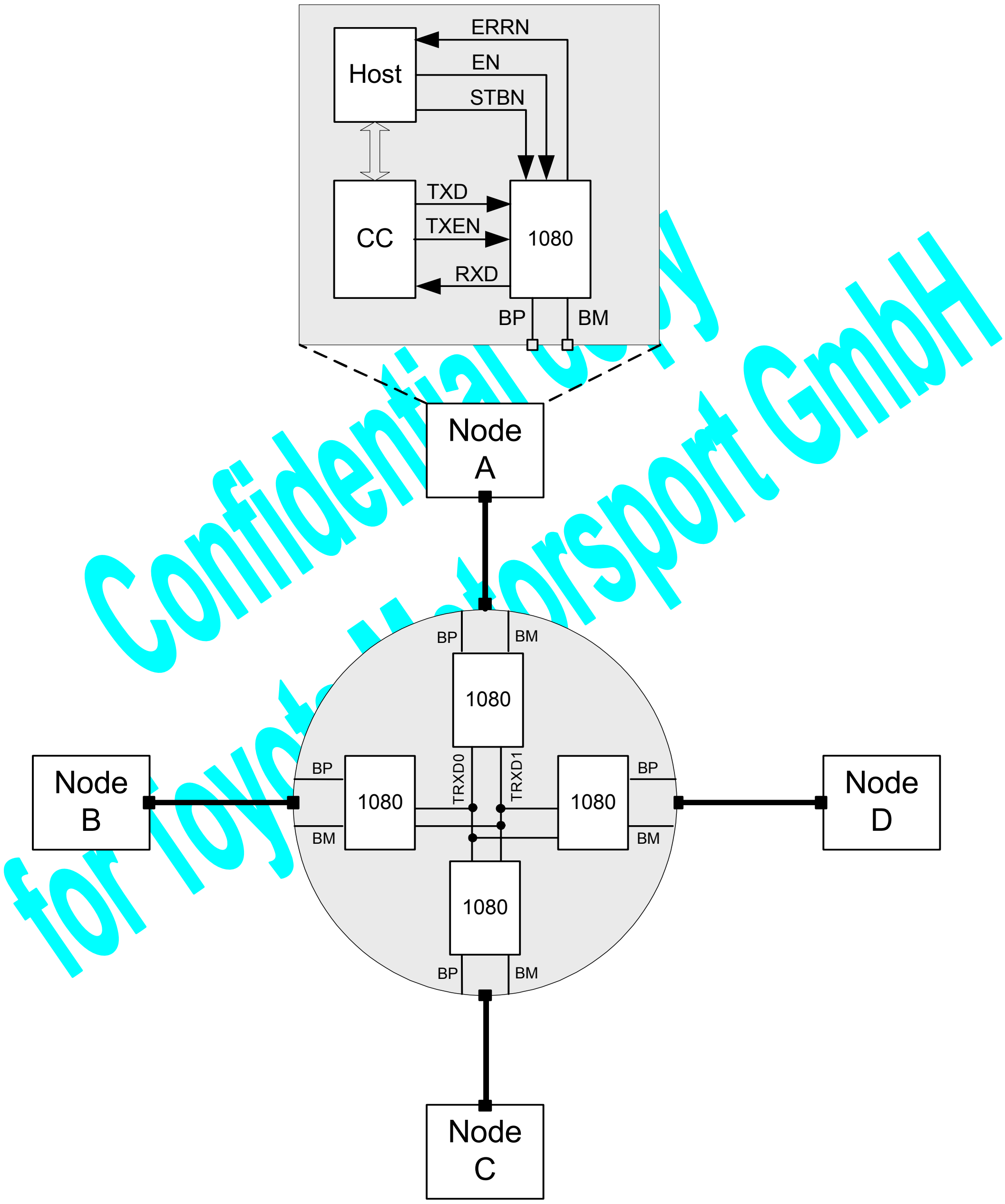


Figure 3-1: Application of TJA1080 in FlexRay systems

### 3.1 Application as node transceiver

As node transceiver, the TJA1080 provides the physical link between communication controller (CC) and the physical medium. The CC outputs a serial transmit data stream to the TXD input of the TJA1080 transceiver. If at the same time the TXEN signal from the CC is LOW, this data stream is regarded as valid and thus converted into a differential voltage signal at the bus terminals BP and BM. For TXD LOW the driver directs a positive current into BM and a negative current into BP. This current results in a negative differential voltage between BP and BM with the bus assuming the *Data_0* state. For TXD HIGH the driver directs a positive current into BP and a negative current into BM. This current results in a positive differential voltage between BP and BM with the bus assuming the *Data_1* state. If the TXEN signal is HIGH, the transmitter is switched off regardless of the TXD signal. If no bus driver is actively driving the bus, the bus is found itself in *Idle* state. In *Idle* state both BP and BM are biased to nominal 2.5V by the receiver input pins and the nominal differential voltage between BP and BM is typically 0V.



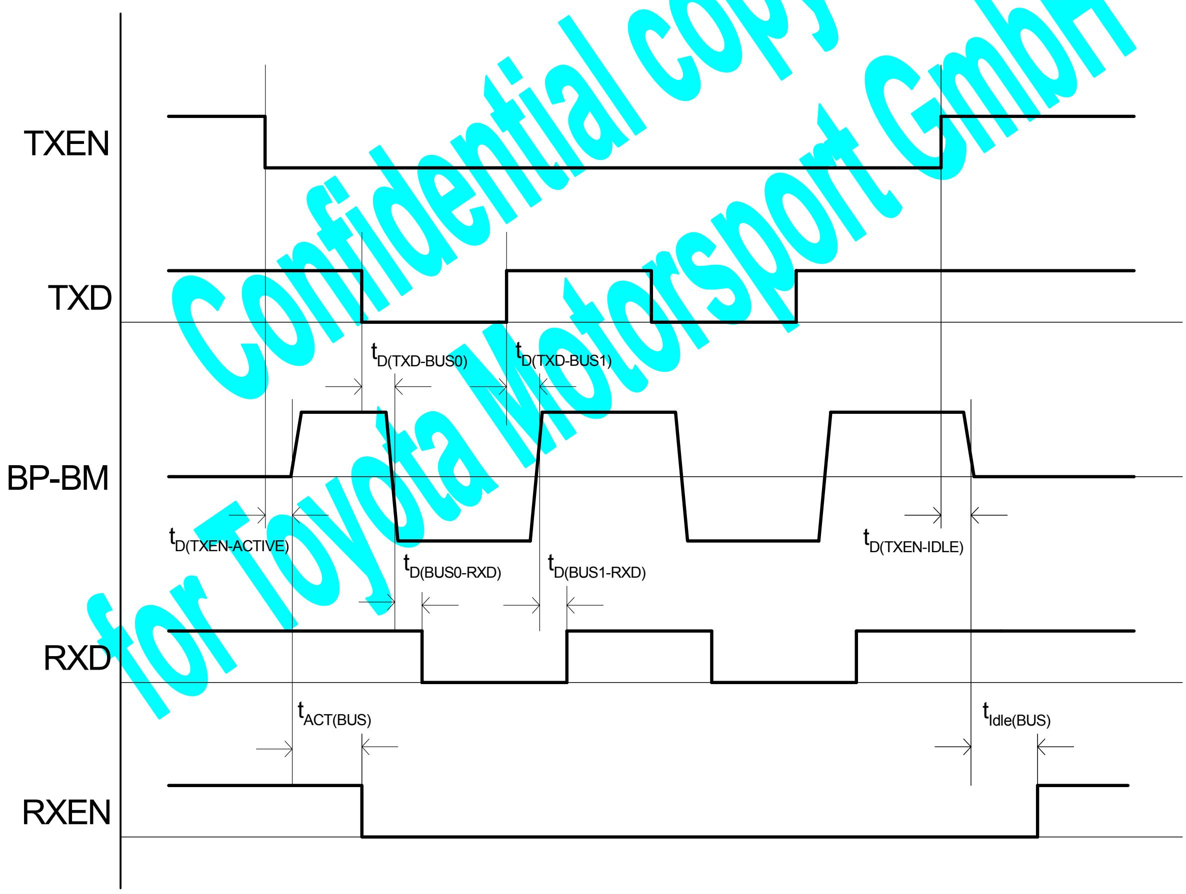


Figure 3-2: Transmit and receive timing characteristics

The receiver converts the differential bus signal to a logic level signal, which is output at RXD. The serial receive data stream is provided to the communication controller for decoding. In addition the TJA1080 indicates whether the bus is in *Idle state* or one of the *Active* states (*Data_1* or *Data_0*). If *Idle* is detected on the bus, RXEN will signal a HIGH level, otherwise RXEN is at LOW level (during frame transmission). While the communication controller does not make use of this signal, a bus guardian may use RXEN to check for bus *Idle* during the Network Idle Time. The principle timing of TXEN, TXD, BP - BM and RXD is illustrated in Figure 3-2.

### 3.2 Application as star transceiver

In an active star coupler, several TJA1080 transceivers are connected via their pins TRXD0 and TRXD1. The bus pins BP and BM of each TJA1080 represent one branch of the star network . An incoming data stream on one branch is transferred to the other branches via the signals TRXD0 and TRXD1. Up to 16 TJA1080 devices can be connected, resulting in a maximum of 16 branches.

After wakeup or after ramp-up of the Vcc supply voltage, the TJA1080 finds itself in *star_idle* state. (For the reference state diagram in star configuration please refer to the current data sheet/device specification [1]). In this state the bus (BP and BM) as well as the TRXD lines are configured as input. When activity is detected on a branch, the corresponding TJA1080 transceiver configures its TRXD0 and TRXD1 pins as output while its bus pins stay input *(star_receive* state).

The activity on the TRXD lines will configure the TRXD0 and TRXD1 pins of the other star transceivers as input but switch their bus terminals BP and BM as output (*star_transmit* state). Therefore, the TRXD0 and TRXD1 input signal would be transferred into the corresponding bus signal (Data_0 or Data_1). This way an incoming data stream on one branch is transferred to all other branches of the active star coupler.

# 4. NODE APPLICATION

## 4.1 How to select node configuration

To use the TJA1080 in a node application, the TJA1080 has to be configured in node configuration. Choosing the configuration can be performed following first battery startup procedure only. Connecting pin TRXD0 and TRXD1 to GND configures the transceiver in node configuration. The configuration gets locked once the internal PWON flag is cleared. In node configuration, the PWON flag is cleared with transition to Normal mode. To change the configuration, a new power-on cycle is necessary.

## 4.2 Low-power management

In node configuration, the TJA1080 offers five different operating modes: Normal, Receive-only and the three low power modes Standby, Goto-Sleep and Sleep. These modes support three different levels of low-power management as illustrated in Table 4-1. In level 0 the ECU components (voltage regulators, microcontroller, transceiver, peripherals) are active and powered. The TJA1080 is either in Normal or Receive-only mode.

| Low Power Level | Operating Mode of the TJA1080 | Vcc Supplyfor TJA1080 | Vcc Supply for Host | Power Consumption |
|---|---|---|---|---|
| Level 0 (bus active) | Normal/ Receive-Only | Active | Active | Normal |
| Level 1 | Standby | Active or Off | Active | Low |
| Level 2 | Sleep | Off | Off | Very Low |

Table 4-1: Low Power Management



The next level of low power, level 1, is achieved with the TJA1080 operating in Standby mode. The microcontroller is typically powered, but some peripherals and the Vcc supply for the transceiver itself may become un-powered by switching off the corresponding voltage regulators. These voltage regulators are then controlled by the INH2 output of the TJA1080.

The low power level 2 is linked to the Sleep mode of the TJA1080. In Sleep mode the external voltage regulator(s), supplying the transceiver, host and other peripherals, are typically switched off via the INH1 and INH2 output signal. While this will leave the host microcontroller and other peripherals completely un-powered, the TJA1080 keeps still powered via the battery supply pin VBAT. This supply is needed to maintain wakeup capability. The low power level 2 allows for minimum current consumption on ECU level.

## 4.3 Operating Modes

The TJA1080 offers five different operation modes, establishing a low-power management with three different levels as described above. For the reference state transition diagram please refer to the data sheet/device specification [1].

#### 4.3.1 Normal Mode

For normal network communication the Normal mode is chosen. The digital bit stream input at TXD and TXEN is transferred into corresponding analog bus signals. Simultaneously, the transceiver monitors the bus, converting the analog bus signals into the corresponding digital bit stream output at RXD. The external voltage regulators are active, the bus lines are biased to Vcc/2 and the transmitter is enabled. The Normal mode is entered by setting STBN=1 and EN=1.

#### 4.3.2 Receive-Only Mode

The Receive-Only mode realizes a listen-only behaviour. The node is only allowed to receive messages from the bus but not to transmit onto the bus. The digital bit stream from the communication controller via TXD and TXEN is ignored. In this way a node can be prevented from influencing the bus. The Receive-only mode is entered by setting STBN=1 and EN=0.

#### 4.3.3 Standby Mode

In Standby mode the current consumption is reduced to a minimum. The transmitter and normal receiver are deactivated. The INH2 output signal is floating, which will disable voltage regulator(s), controlled by INH2. The bus pins BP and BM will be weakly terminated to GND level. In Standby mode the transceiver still monitors the different channels for wakeup events (bus wakeup, local wake-up via WAKE or STBN pin). Once a wakeup event has been detected, the RXD and RXEN pins will switch from HIGH to LOW level and stay LOW until Normal or Receive-Only mode is entered. Moreover, the INH2 signal becomes switched on again. The Standby mode is selected with STBN=0 and EN=0.



#### 4.3.4 Sleep Mode

The only difference between Standby and Sleep mode is that both INH1 and INH2 are floating in Sleep mode. Once a wakeup event is detected the RXD and RXEN pins will switch from HIGH to LOW level and stay LOW until Normal or Receive-Only mode is entered. Moreover, both INH1 and INH2 become switched on again. The usual way to enter Sleep mode is via the Goto-Sleep mode. If the Goto-Sleep is selected for longer than the “minimum hold time of goto-sleep command” [1] while the wakeup flag is reset, the transceiver will enter the Sleep mode.

#### 4.3.5 Goto-Sleep mode

The Goto-Sleep mode has the meaning of a command rather than the meaning of a typical operating mode. It is used only to put the TJA1080 into Sleep mode. Due to the spread of the “minimum hold time of goto-sleep command” the Goto-Sleep mode must be actually selected for longer than the maximum value in order to make sure the Sleep mode will be entered reliably. By entering Goto-Sleep mode the transceiver behaves as in Standby mode, so the transmitter is disabled, the bus lines are terminated to GND, the wakeup detection circuitry is active and INH1 is switched on while INH2 is switched off. The Goto-Sleep mode is selected with STBN=0 and EN=1.

### 4.4 Wakeup

There are three different wakeup channels in node configuration: Bus wakeup, wakeup via WAKE pin, wakeup via STBN pin. For a description of the different wakeup mechanisms refer to 6.

## 4.5 Fault confinement behavior

### 4.5.1 TXEN/BGE Clamping

To prevent dominant clamping of the whole network in case of a faulty TXEN/BGE clamping, the TJA1080 continuously monitors the TXEN and BGE signal. If both signals are active (TXEN=LOW and BGE=HIGH) for longer than $t_{TXEN\_BGE(Clamped)}$ , the TJA1080 will disable the transmitter and the corresponding TXEN_BGE Clamped flag will be set. Once TXEN becomes HIGH or BGE LOW again, the TXEN_BGE Clamped flag is reset and the transmitter is enabled.

### 4.5.2 Supply voltage monitoring

The TJA1080 continuously monitors the supply voltage on Vcc, Vio and VBAT. In case an under-voltage condition is detected (i.e. supply voltage lower than the defined operating range), the TJA1080 enters autonomously a low-power mode to provide defined fail-silent low-power system behavior. Table 4-2 shows the condition for under-voltage detection along with the resulting mode change. This mode change disables the mode control via STBN and EN. In case of a VBAT under-voltage detection mode control via STBN and EN is enabled automatically with recovery of the battery voltage. In case of Vio or Vcc under-voltage condition mode control via STBN and EN is not automatically enabled with recovery of the corresponding voltage, rather a wakeup is needed (wakeup by bus, wakeup via WAKE pin, wakeup via STBN).



| Under-voltage on | Detection condition | Mode change to |
|---|---|---|
| $V_{CC}$ | $V_{CC} < V_{CC(UV)}$ for longer than $t_{DET(UVVCC)}$ | Standby (→ INH2 float.) |
| Vio | $Vio < Vio_{(UV)}$ for longer than $t_{DET(UVVio)}$ | Sleep (→ INH1 and INH2 float.) |
| $V_{BAT}$ | $V_{BAT} < V_{BAT(UV)}$ ; no timeout | Sleep (→ INH1 and INH2 float.) |

Table 4-2: Supply voltage monitoring and detection

## 4.6 Hardware application

As an example, a possible hardware application of the TJA1080 is shown in Figure 4-2. Here the 3.3V regulator, supplying the host and the CC, and the 5V regulator, supplying the transceiver, are controlled by INH1, whereas the 5V regulator for peripheral devices is controlled by INH2. Thus the peripheral devices would become un-powered in Standby mode, while the host and transceiver supply voltage would be only switched off in Sleep mode.

### 4.6.1 Communication Controller Interface

The communication controller interface comprises the signals TXD, TXEN and RXD. The data stream from the CC to be transmitted onto the bus is input at TXD. To enable the transmitter, the CC has to force TXEN to LOW level. The receiver converts the analog bus signal into a digital data stream, which is output at RXD for decoding within the CC.

An exemplary TXD, TXEN sequence during frame transmission along with the corresponding bus signal and received data stream at RXD is shown in Figure 4-1.

To reduce transient current peaks within the transceiver, a series resistor of typ. 1kOhm can be inserted into the RXD line. However, the signal rise/fall times should not exceed 5ns.

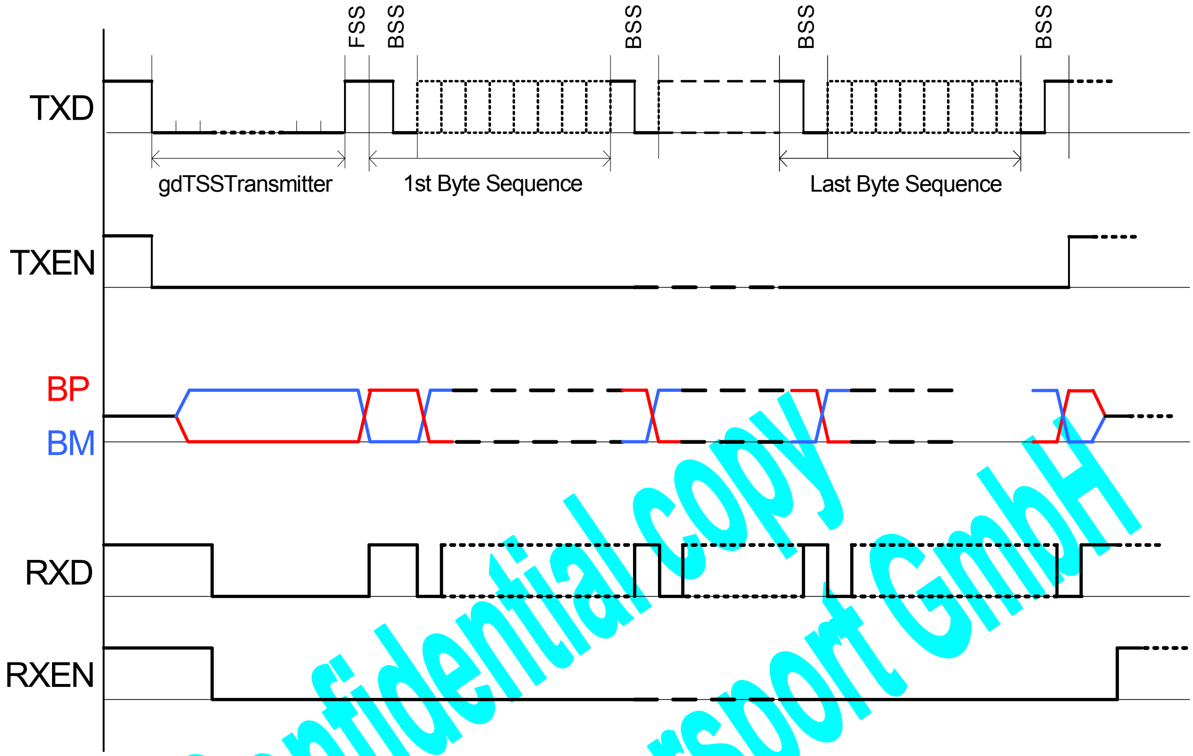


Figure 4-1: TXD, TXEN, BP, BM, RXD, RXEN during frame transmission



### 4.6.2 Host Interface

The host interface comprises the signals STBN and EN for mode control of the TJA1080 and the ERRN signal for reading diagnosis and status information.

### 4.6.3 Bus Guardian Interface

In case a bus guardian is used, the interface to the bus guardian consists of the signals BGE and RXEN. When the node´s specific time slot is reached, the bus guardian forces the BGE signal to LOW level during the corresponding time slot, thus allowing the CC to access the bus. A typical application with an external bus guardian device is shown in Figure 4-3. In case no bus guardian is used, the pin BGE shall be connected to Vio level. In case BGE is unconnected, an internal pull-down current forces the input voltage to LOW level, thus disabling the transmitter by default.

### 4.6.4 Bus Interface

The node application in Figure 4-2 shows the typical bus interface circuit for a terminating node. To improve the EMC performance a common mode choke is recommended, especially at high data rates. The choke shall be placed as close as possible to the transceiver bus pins BP and BM. To avoid signal overshoots and ignition of resonance oscillations at the transition to bus Idle, the stray inductance of the common mode choke should be lower than 500nH.

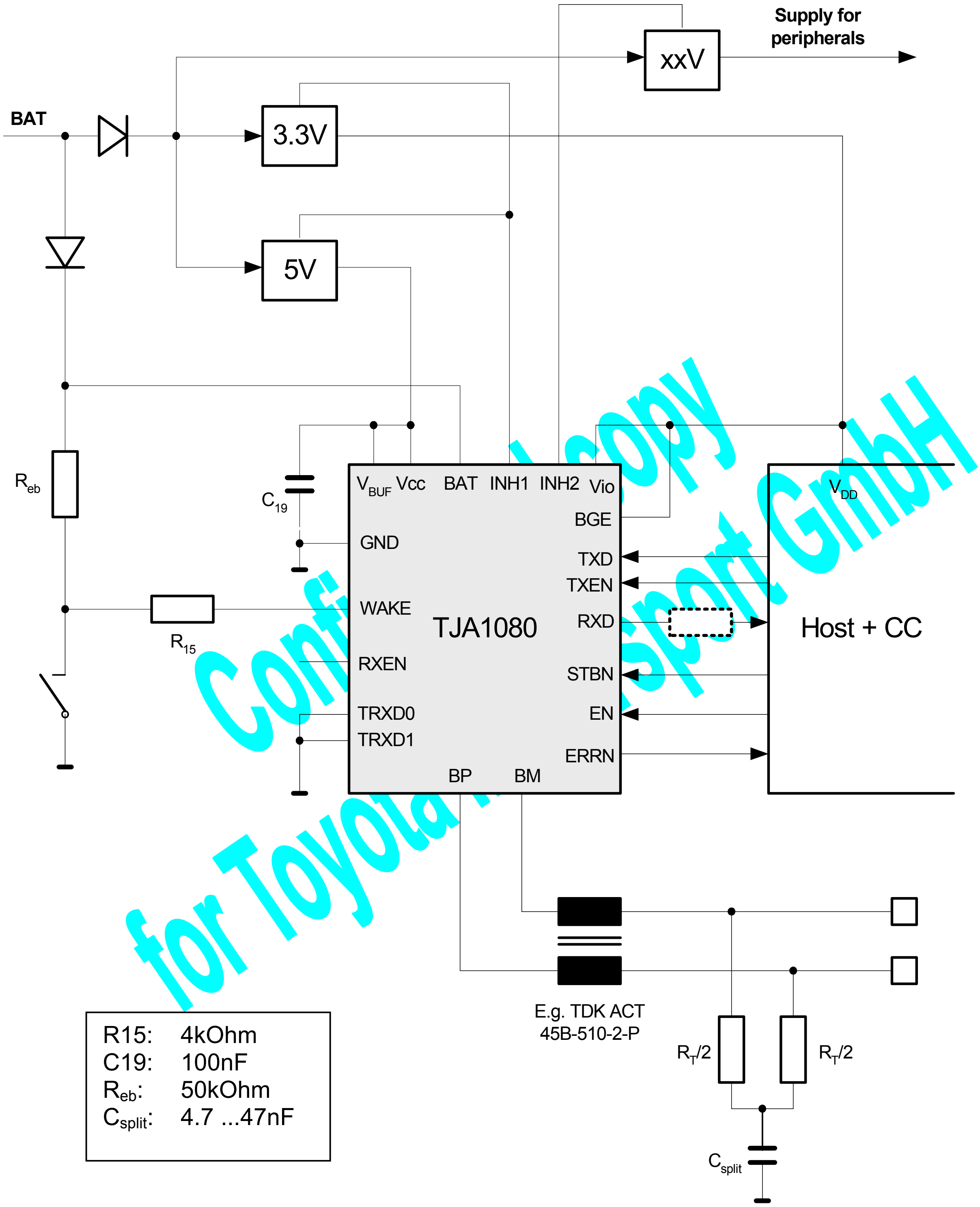




Figure 4-2: Application of TJA1080 in node configuration

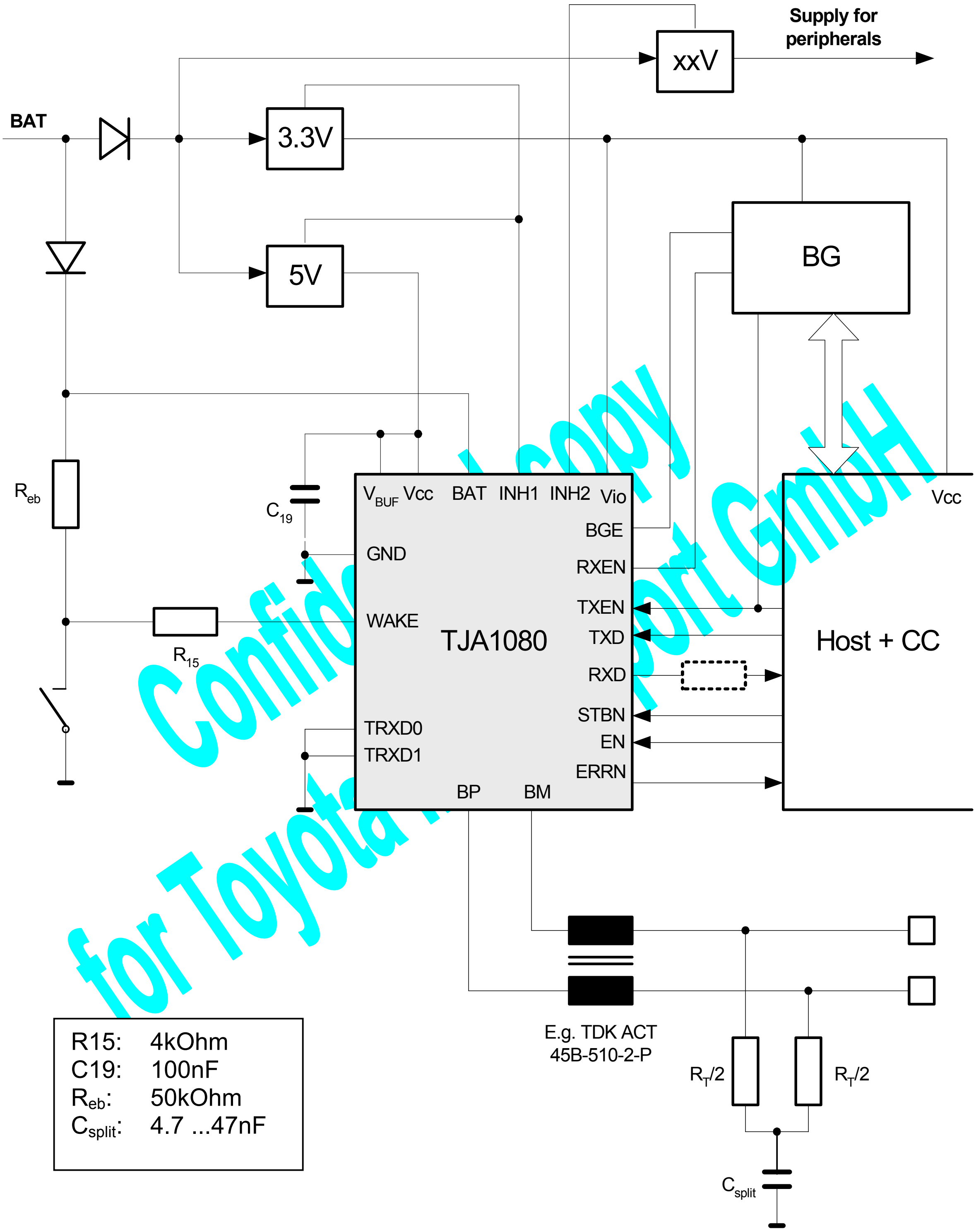


Figure 4-3: Application of TJA1080 in node configuration with decentralized bus guardian

For bus termination it is highly recommended to use the so-called split termination as shown in Figure 4-2. EMC measurements have shown that the split termination is able to improve significantly the signal symmetry between BP and BM, thus reducing emission. Recommended values for the split termination capacitor are within the range from 4.7nF to 47nF.

The total series resistance between the transceiver bus pins BP and BM and the ECU connector pins BP_ECU and BM_ECU shall not exceed 500mΩ.

### 4.6.5 Other Interfaces

#### 4.6.5.1 PIN WAKE

A pull-up resistor $R_{eb}$ is needed to pull the pin WAKE back to VBAT level after release of the low-side switch. Recommended value is 50kΩ. To protect the transceiver from a too high output current, which would flow in case of a loss of GND situation while the low-side switch is active, a series resistor (R15) of about 4kΩ should be connected to the pin WAKE.

In case the pin WAKE is not needed, it is recommended to connect this pin directly to GND level.

#### 4.6.5.2 PIN INH1 and INH2

The intention of the pin INH1 and INH2 is to control voltage regulators within the ECU. In Figure 4-2 and Figure 4-3 the INH1 output pin controls the voltage regulator for host, CC and transceiver. In Sleep mode the INH1 pin becomes floating. Due to the typical pull-down behavior of the Inhibit input pin of common voltage regulators, this results in a LOW signal at the Inhibit input, thus disabling the voltage regulator(s) in Sleep mode. Similarly the INH2 output pin may control the voltage regulator of other peripherals. It is switched off, when the transceiver is in Sleep as well as in Standby mode. Once a wakeup is detected, both INH1 and INH2 are immediately switched on to allow fast recovery of supply voltages.

In case the pin INH is not used for voltage regulator switching, it can be simply left open.



### 4.6.6 Power supply for the TJA1080

#### 4.6.6.1 Vcc Pin

The primary power supply for the TJA1080 is the Vcc supply voltage. This voltage directly powers the internal transmitter and receiver circuit. The VBUF pin is needed in star configuration only. In node applications, this pin shall be directly connected to the Vcc pin. To stabilize the Vcc voltage a buffer capacitor (C19) should be connected as close as possible to the VBUF pin. Recommended value is 100nF.

#### 4.6.6.2 VBAT pin

The secondary supply voltage is the VBAT supply voltage. In low-power mode the wakeup circuit is powered from this voltage, since the Vcc voltage is typically not available in low-power mode.

#### 4.6.6.3 Vio Pin

The pin Vio is connected to the host supply voltage to provide the proper voltage reference for the input threshold of digital input pins and for the HIGH voltage of digital outputs. The TJA1080 provides a continuous level adaptation from as low as 2.2V to 5V. If the pin Vio is disconnected, an under-voltage condition on Vio will be detected and the transceiver will be autonomously forced into Sleep mode in order to provide defined fail-silent low-power system behavior.

# 5. ACTIVE STAR APPLICATION

## 5.1 How to select star configuration

To put the transceiver into star configuration, the pins TRXD0 or TRXD1 shall be connected to the VBUF pin via a pull-up resistor and the STBN pin shall be connected to GND level. The configuration gets locked once the internal PWON flag is cleared. (In node configuration, the PWON flag is cleared with transition to Normal mode. In star configuration, ramping up the Vcc supply voltage will clear the PWON flag.) To change the configuration, a new battery start-up procedure is necessary.

## 5.2 Low power management

An active star coupler, built up by TJA1080 transceivers in star configuration, features an autonomous power moding. When there is no activity on all branches for longer than $t_{star\_idle(noact)}$ [1], the active star coupler autonomously enters a sleep-like state. In this state the Vcc supply for the star transceivers is typically disabled, reducing the current consumption to a minimum, and the function is reduced to monitoring the different branches for a wakeup pattern. Once a valid wakeup pattern (see 6.1) is detected on a branch or another wakeup condition is present (falling edge at WAKE pin, rising edge at STBN or TRXD activity), the voltage regulator is activated again and the active star coupler resumes normal operation.

## 5.3 Wakeup

Like in node configuration, the TJA1080 can receive a wakeup via the bus, the pin WAKE or the pin STBN. For a description of the different wakeup mechanisms refer to chapter 6. In star configuration the TJA1080 can additionally be woken up by TRXD activity. This happens when either the TRXD0 or the TRXD1 line becomes LOW for at least $t_{ACT(TRXD)}$.

## 5.4 Fault confinement behaviour

The fact that the different branches of an active star coupler are actually electrically decoupled from each other allows for superior fault confinement behaviour. Below two fault assumptions are discussed in more detail: Bus clamping and TXEN/BGE clamping. The third section describes the supply voltage monitoring feature of the TJA1080.



### 5.4.1 Bus clamping

If a branch is continuously active due to a physical fault on the bus lines, that means, the bus has not become *Idle* within the timeout $t_{star\_receive(active)}$ , the TJA1080 will detect this bus error condition after the timeout $t_{star\_receive(active)}$ [1] and excludes this branch from the rest of the network. This way the fault keeps confined to the corrupted branch only without affecting the other branches. Upon detection, the star transceiver goes autonomously to *star_locked* mode. In this mode the bus transmitter is switched off and both the TRXD0 and TRXD1 pins are released to reflect *Idle* state. Once both the bus and TXEN show *Idle* again for longer than $t_{star\_locked(idle)}$ [1], the star transceiver returns to *star_idle* state.

### 5.4.2 TXEN clamping

To prevent dominant clamping of the whole network in case of a faulty TXEN signal clamping, the TJA1080 continuously monitors the TXEN signal. If the TJA1080 is in *star_transmit* state due to TXEN activity for longer than $t_{star\_transmit(active)}$ [1], the TJA1080 automatically goes into *star_locked* state, thus disabling its transmitter. The transceiver switches back to *star_idle* once both TXEN and the bus have become *Idle* again.

### 5.4.3 Supply voltage monitoring

The TJA1080 in star configuration continuously monitors the supply voltage on Vcc/VBUF and Vio. In case an Vcc under-voltage condition is detected (i.e. supply voltage lower than the defined operating range), the TJA1080 enters autonomously the *star_sleep* mode to provide defined fail-silent low-power system behavior. As a result INH1 and INH2 become floating, thus disabling the corresponding voltage regulator. Table 5-1 shows the condition for under-voltage detection along with the resulting action taken by the transceiver. There is no under-voltage detection for VBAT in star configuration. The reason is that the star transceiver should try to continue operation as long as Vcc/VBUF is available.

| Under-voltage on | Detection condition | Behaviour upon detection |
|---|---|---|
| $V_{CC}$/VBUF | $V_{CC} < V_{CC(UV)}$ for longer than $t_{DET(UVVCC)}$ | Standby (→ INH2 float.) |
| Vio | Vio < $Vio_{(UV)}$ for longer than $t_{DET(UVVio)}$ | INH1 is switched off |
| $V_{BAT}$ | No detection | --- |

Table 5-1: Supply voltage monitoring in star configuration



## 5.5 Hardware application

The concept of the TJA1080 as a star transceiver allows integrating an active star into an ECU. In this case the communication controller has direct access to one of the star transceivers. The second section describes this integrated solution, while the first section shows the hardware application of the standalone solution.

### 5.5.1 Standalone solution

A typical hardware application of the TJA1080 in a star application is shown in Figure 5-1. As an example three TJA1080 devices are used to build an active star coupler with three branches. The different devices are interconnected via the TRXD0 and TRXD1 pins, respectively. The two connecting lines are forming the inner bus line of the active star coupler. Both the TRXD0 and TRXD1 pins are connected to the $V_{BUF}$ pin via a pull-up resistor. The recommended value is 220Ω times the number of connected TJA1080 devices. In this example of three devices Rx10 and Rx11 have the value of 600Ω. The capacitor $Cx_{stor}$ at the $V_{BUF}$ pin acts as energy storage, when the Vcc voltage is not available (during star_sleep). This way wakeup symbols received at a branch can be transferred to all other branches before the Vcc voltage has ramped up. Recommended value for $Cx_{stor}$ is 33uF. The additional capacitor Cx20 at the VBUF pin provides the necessary peak current when the bus is switching from Idle to active state. This capacitor shall be placed as close as possible to the VBUF pin. In this example there is a bus termination between the bus terminals BP and BM. Depending on the network topology the bus terminals of a star transceiver may even be un-terminated. When a termination is used, it is highly recommended to build a so-called split termination as shown in the example of Figure 5-1.

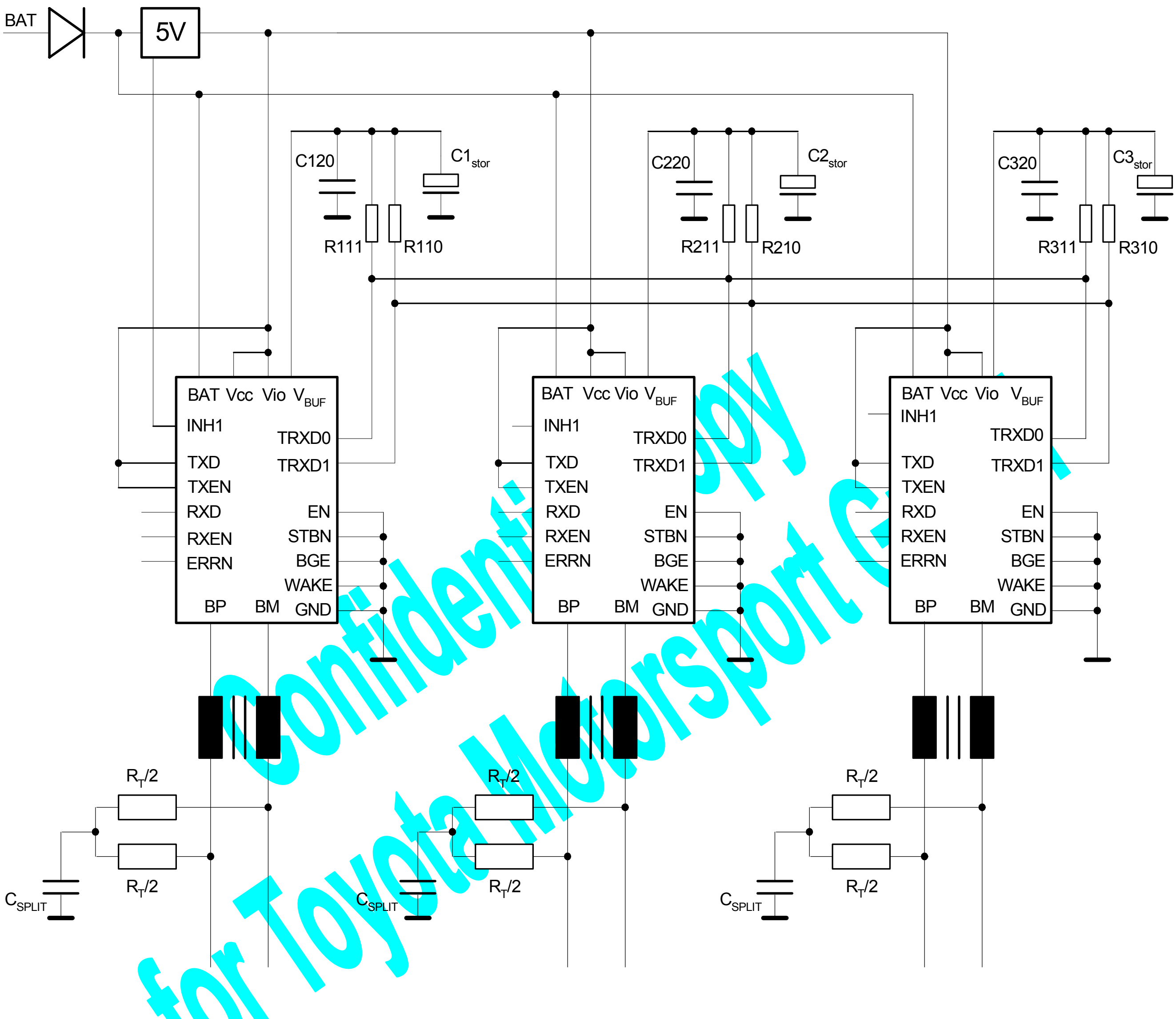




Figure 5-1: Active star application with TJA1080

### 5.5.2 Integration of an active star coupler into an ECU

A typical hardware application without a bus guardian is shown in Figure 5-2.

The interface to the communication controller comprises the signals TXD, TXEN and RXD. The CC can communicate to the rest of the network via this interface in a similar way like in node configuration. Signals applied at TXD and TXEN are transmitted on the bus terminals BP and BM as well as on TRXD0 and TRXD1. RXD always reflects the signal on the attached branch.

The interface to the host may comprise the signals STBN, EN and ERRN. STBN may be used to wakeup the active star coupler directly from the host. ERRN and EN may be used for reading the status register of the transceiver to which the host is connected. Notice that the ERRN features an open drain output in star configuration, while in node configuration the ERRN pin is driven by a push-pull stage. Therefore, an external pull-up resistor (R13) to Vio level is needed. For reading the status register refer to chapter 7.

To release the transmitter for sending via TXD and TXEN the BGE pin has to be connected to Vio level. For all other star transceivers, which are not triggered via TXD and TXEN, it is recommended to connect the BGE pin to GND level.

As shown in Figure 5-2 an external switch may be used to wakeup the whole active star coupler if needed. In case the pin WAKE is not needed, it shall be connected directly to GND level.

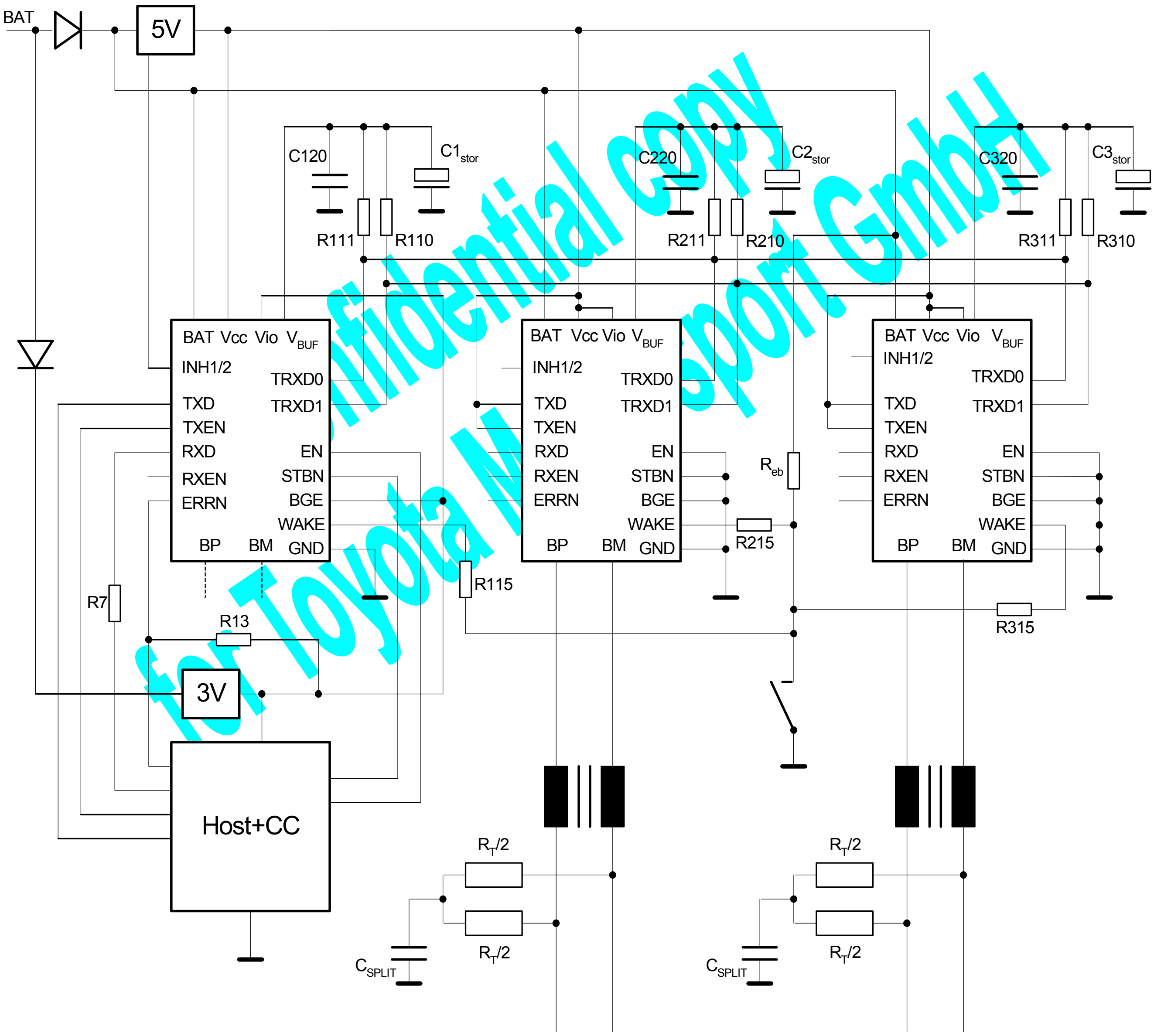



Figure 5-2: Integration of Active star within an ECU (application without bus guardian)

Typical values for the components shown in Figure 5-2 are listed in Table 5-2.

| Component | Typical value |
|---|---|
| Cx20 | 100nF |
| $Cx_{stor}$ | 33uF |
| Rx10 | 220Ω x Number of Transceivers |
| Rx11 | 220Ω x Number of Transceivers |
| R13 | 10kΩ |
| Rx15 | 4kΩ |
| R7 | 1kΩ |
| $R_{eb}$ | 50kΩ |

Table 5-2: Typical values



## 5.6 First battery start-up procedure

This section describes what happens when an active star coupler like in Figure 5-1 is supplied for the first time with the battery voltage. With the battery voltage crossing the power-on reset threshold, both the INH1 and INH2 are switched on, thus starting the attached voltage regulators and simultaneously ramping up the Vcc and VBUF supply voltage. Due to the pull-up resistors, the voltage at TRXD0 and at TRXD1 follows the VBUF voltage. This causes the TJA1080 to operate in star configuration. As long as the Vcc voltage is below the undervoltage detection threshold, the TJA1080 finds itself in *star_standby* state. Once the Vcc has ramped up, the PWON flag is reset and the star configuration gets locked. Changing the configuration is possible only with a new battery startup procedure. If the Vcc voltage does not ramp up within $t_{DET(UVVcc)}$ [1] the TJA1080 will go automatically into *star_sleep* for fail-silent reasons.

## 5.7 Truncation

An active star coupler built up by TJA1080 transceivers may truncate the first dominant period following *bus_idle*, i.e. the transmission start sequence and the first Logic_0 period of the wakeup symbol is subject to truncation. The value of truncation is determined by the sum of the bus activity $t_{ACT(BUS)}$ [1] and TRXD activity detection time $t_{ACT(TRXD)}$ [1]. The interval by which the transmission start sequence is shortened from a transmitting node M to a receiving node N is denoted $dTruncation_{M,N}$. The effect of truncation of the transmission start sequence is shown in Figure 5-3.

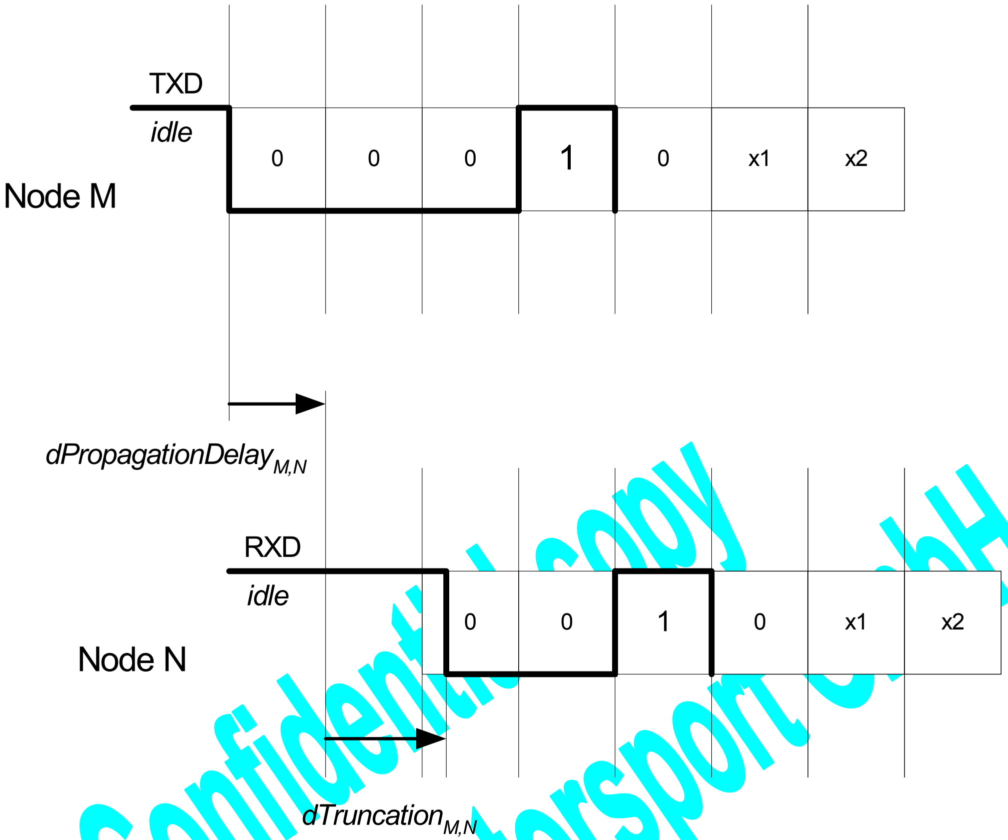


Figure 5-3: Effect of truncation

# 6. WAKEUP

In node as well as in star configuration there are at least three different wakeup channels available: wakeup by bus, wakeup via WAKE pin and wakeup via STBN pin.

## 6.1 Wakeup by Bus

A bus node can wake up the other bus nodes by transmitting a wake-up pattern on the bus.

### 6.1.1 Detection mechanism

While the TJA1080 is in a low-power mode (Standby, Goto-Sleep, Sleep, star_standby, star_sleep), the TJA1080 monitors the bus for a wakeup event. A bus wakeup event will be reliably detected, if a wake-up pattern is received within a time window of $t_{DET(TOTAL)(WAKE)}$ [1]. The wake-up pattern is a sequence of

- *Data_0* for at least $t_{DET(ZERO)(WAKE)}$ [1],
- followed by *Data_1* or *Idle* for at least $t_{DET(IDLE)(WAKE)}$ [1],
- followed by *Data_0* for at least $t_{DET(ZERO)(WAKE)}$ [1],
- followed by *Data_1* or *Idle* for at least $t_{DET(IDLE)(WAKE)}$ [1],

as illustrated in Figure 6-1.



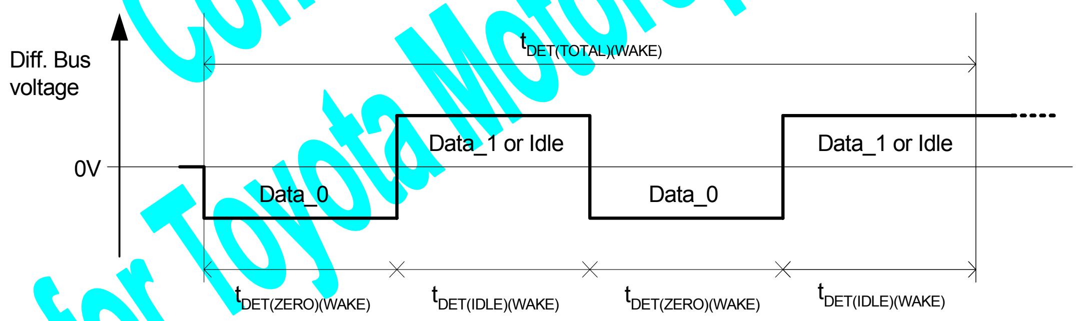


Figure 6-1: Bus wakeup detection

### 6.1.2 Generation of the wakeup pattern with TXD and TXEN

The wakeup pattern can be regarded as a sequence of two wakeup symbols, each being defined as a sequence of a configurable number of *pdBit* times logic LOW at TXD and TXEN, followed by a configurable number of *pdBit* times logic HIGH at TXD and TXEN. A recommended wakeup symbol implementation is shown in Figure 6-2, consisting of a logic LOW period of 6us length and a logic HIGH period of 18us length. The communication controller has to repeat the wakeup symbol for a configurable number of times. At least two wakeup symbols are needed to wakeup a single TJA1080 transceiver. The minimum number for cluster wakeup depends on the number of active star couplers, because each star coupler would consume some wakeup symbols while passing the active star coupler. In case of the recommended wakeup symbol above the CC is recommended to repeat the wakeup symbol at least 10 times for a cluster wakeup with two cascaded active stars and at least 6 times for a cluster wakeup with only one active star.

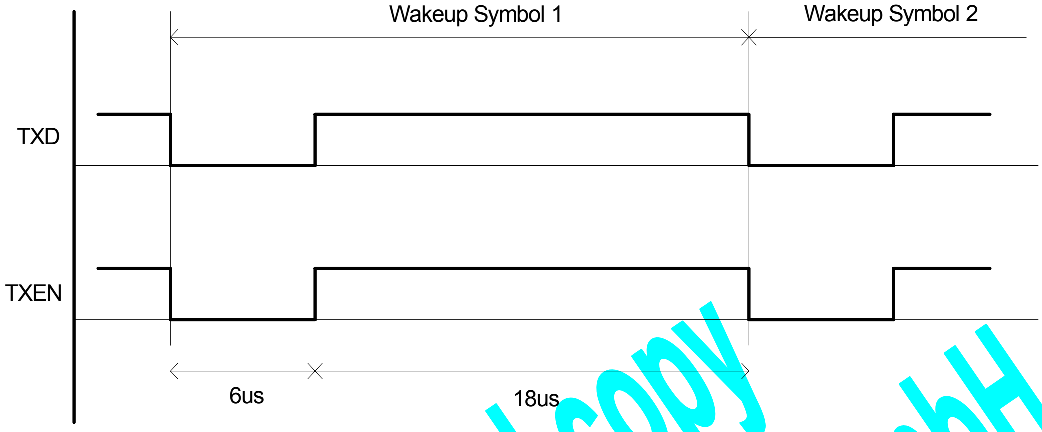


Figure 6-2: Recommended wakeup symbol



### 6.1.3 Generation of the wakeup pattern as a dedicated data frame

The TJA1080 allows a bus wakeup by transmission of a dedicated data frame. An example for 10Mbit/s is shown in Figure 6-3. To represent a wakeup symbol, 6 data bytes x00 followed by 6 data bytes xFF are sent onto the bus. Due to the slow behavior of the low-power receiver Due to the slow behavior of the low-power receiver the interruptions of the wakeup pattern from the Byte Start Sequence bits are not visible for the low-power receiver.

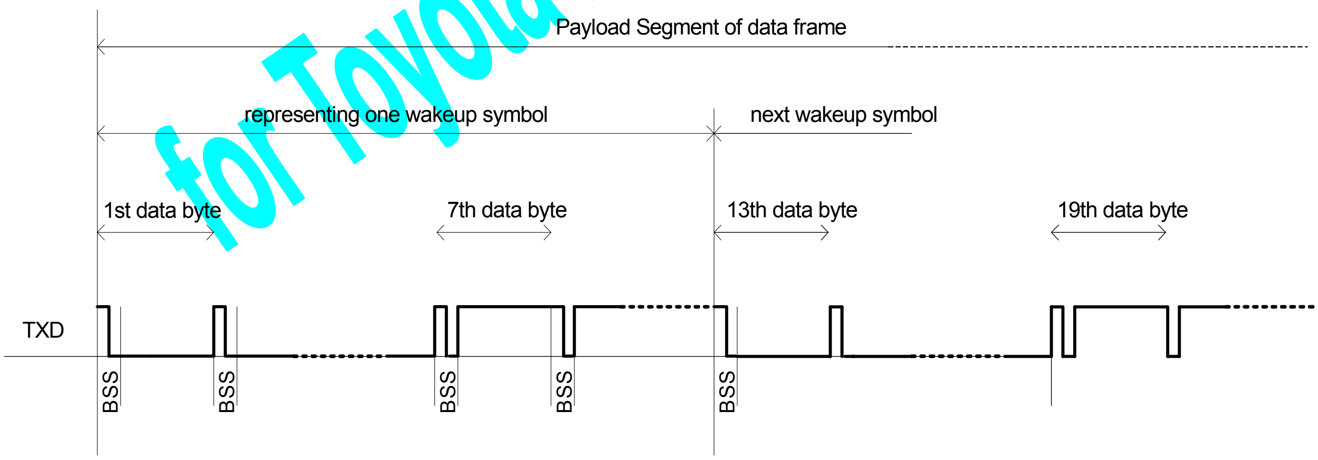


Figure 6-3: Payload segment representing a wakeup symbol at 10Mbit/s

## 6.2 Wakeup via Wake pin

The pin WAKE can be used to signal a local wakeup event to the transceiver. A falling edge at pin WAKE followed by a LOW period of longer than $t_{WU(WAKE)}$ [1] will be reliably detected as a local wakeup event. The pin WAKE is not sensitive to a rising edge. In case the pin WAKE is not used, it is recommended to connect this pin directly to ground level.

## 6.3 Wakeup via STBN pin

Besides a wakeup from bus or the pin WAKE, the TJA1080 can directly receive a wakeup event from the host via a rising edge at the pin STBN. This wakeup mechanism is available only if the Vio and VBAT supply voltages are available.

# 7. STATUS AND DIAGNOSIS INFORMATION

This chapter deals with reading the status register and the overall error flag. It is the same for node and star configuration.

## 7.1 Reading the status register

A status register is implemented that can be readout at ERRN by using EN as clock. In Table 7-1 the different status bits are given. The status register is accessible in node as well as in star configuration. In Figure 7-1 the timing diagram is shown. A negative edge at EN starts the readout. Within $t_{VALID(ERRN)}$ [1] after the first edge at EN, ERRN will become HIGH, if it has been LOW before. On the second negative edge at EN the first status bit (S0) will be shifted out. The status bits are valid after $t_{VALID(ERRN)}$ [1]. If no edge is detected on EN for longer than $t_{NOACT(EN)}$ [1], the transceiver enters the state selected at EN and STBN (in node configuration).

Reading the status register is possible only if the Vio and VBAT voltages is are available.

The minimum clock period at EN for reading the status register is 1us. At this speed the capacitive load at the ERRN pin should not exceed 20pF. In case of a higher capacitive load the clock period should be made longer.

A status bit will be reset only after the status bit has been read and the condition for setting this bit has gone. This way, transient error conditions do not get lost. Accordingly, two subsequent read accesses are necessary in order to get the current status.



| NUMBER | DESCRIPTION |
|---|---|
| S0 | LOCAL WAKEUP; LOW indicates local wakeup |
| S1 | REMOTE WAKEUP; LOW indicates remote wakeup |
| S2 | NODE CONFIG; LOW indicates node configuration |
| S3 | PWON: LOW means PWON flag has been set previously |
| S4 | BUS ERROR: LOW means bus error flag has been set previously |
| S5 | TEMP HIGH: LOW means temp high flag has been set previously |
| S6 | TEMP LOW: LOW means temp low flag has been set previously |
| S7 | TXEN_BGE CLAMPED: LOW means TXEN_BGE flag has been set previously |
| S8 | UVVBAT: LOW means VBAT undervoltage has been detected previously |
| S9 | UVVcc: LOW means Vcc undervoltage has been detected previously |
| S10 | UVVio: LOW means Vio undervoltage has been detected previously |
| S11 | STAR LOCKED: LOW means star_locked state has been entered previously |
| S12 | TRXD COLLISION: LOW means a TRXD collision has been detected previously |

Table 7-1: Status bits of TJA1080

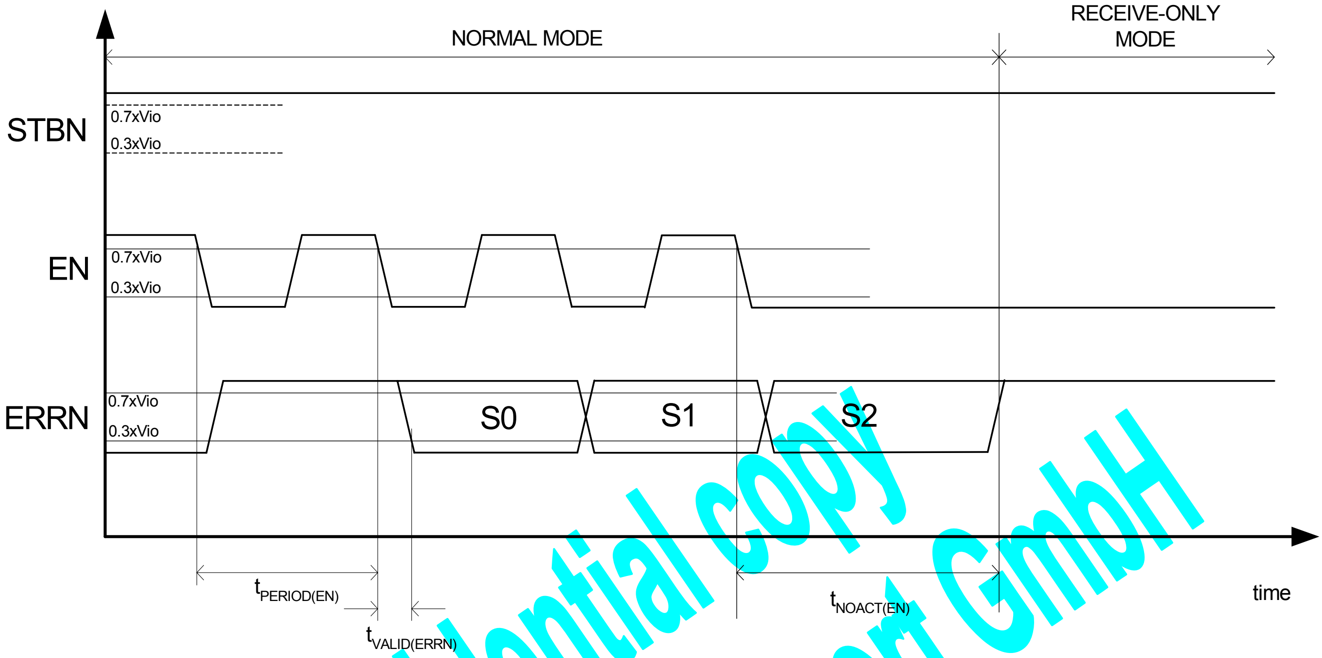


Figure 7-1: Timing diagram for reading the status bits



## 7.2 Overall Error flag

The overall error flag is set when one of the status bits from S5 up to S13 is set. The ERRN pin will be at LOW level, if the overall error flag is set, independent of the operation mode.

## 7.3 ERRN Pin output behaviour

While the ERRN features a push-pull stage in node configuration, in star configuration only the low level is driven actively by an open-drain output. Therefore, an external pull-up resistor is needed at the ERRN pin in star configuration. The open-drain output allows combining the ERRN pins of the active star transceivers.

# 8. PCB LAYOUT

## 8.1 General Guidelines

The following guidelines should be considered for the PCB layout.

- If a common mode choke is used, it shall be placed as close as possible to the transceiver bus terminals BP and BM.
- The tracks for the bus signals BP and BM shall be routed close together in a symmetrical way.
- The bus signal tracks from the transceiver to the ECU connector pins shall be shorter than 10cm.
- The capacitive load between the ECU connector pins BP_ECU and BM_ECU shall not exceed 30pF. Notice this limits the choice for ESD protection components on the PCB.

## 8.2 ESD Protection

The TJA1080 is designed to withstand ESD pulses up to 8kV according to the human body model [5] and thus typically does not need further external protection measures. By using varistors or suppressor diodes in combination with a choke, the ESD performance can be significantly improved on ECU level. Varistors or suppressor diodes are most effective if they are placed close to the ECU connector bus terminals. Tests applied to a bus interface similar to that in Figure 8-1 have revealed ESD protection of more than 8kV on ECU level (ESD standard EN 61000-4-2, C=150pF and R=330Ω). In Figure 8-1 the optional external ESD protection is realized with two clamping diode structures at BP and BM to GND. The clamping voltage of protection devices should be chosen above the maximum battery supply voltage of the system in order not to damage the diodes, if there is a short to battery on the bus lines. To keep the capacitive load seen between the ECU connector pins BP_ECU and BM_ECU low, the parasitic capacitance of such ESD components shall not exceed 40pF.



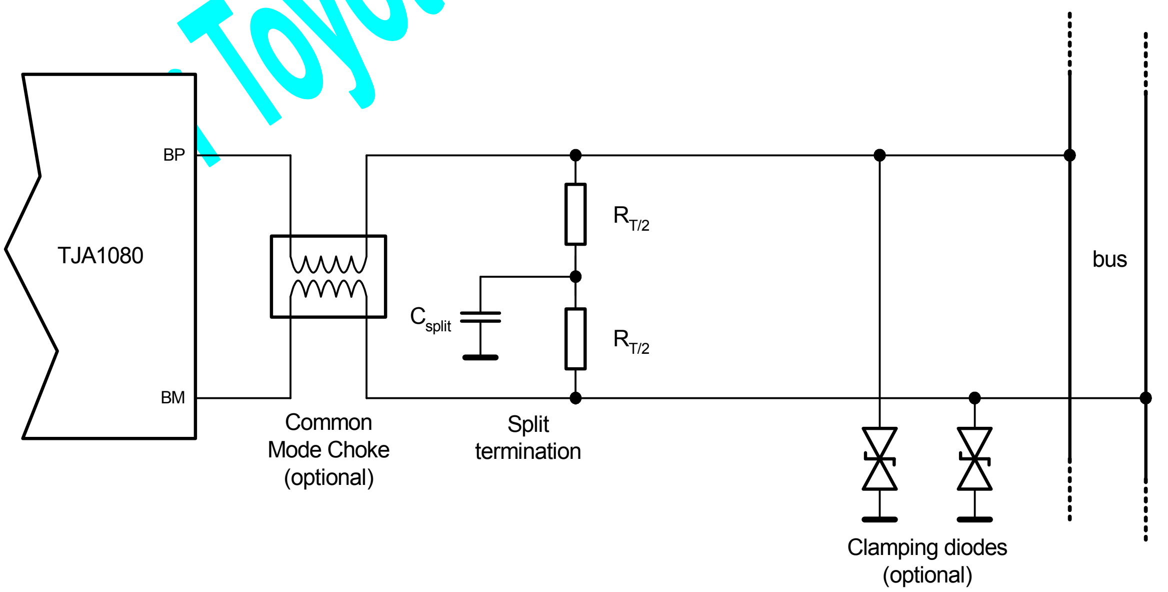


Figure 8-1: Typical ESD Protection circuit

# 9. PROTOCOL CONFIGURATION PARAMETERS

There are protocol configuration parameters, which depend on the physical layer implementation. This chapter gives recommendations on the Transmission Start Sequence and Action Point Offset.

## 9.1 Transmission Start Sequence ("gdTSSTransmitter")

The Transmission Start Sequence has the function to initiate proper connection setup throughout the network and precedes the communication element specific data. The Transmission Start Sequence is transmitted with 1-15 bit times LOW at TXD. The actual number of bit times is configured in the parameter *gdTSSTransmitter* [4].

The connection setup time in an active star coupler may truncate the Transmission Start Sequence. An active star coupler built up by TJA1080 devices allows a maximum truncation of 350ns. In case of only one active star, the transmitted Transmission Start Sequence shall be at least 600ns long. In case of two cascaded active stars, the transmitted Transmission Start Sequence shall be at least 950ns long.

## 9.2 Action Point Offset ("gdActionPointOffset")

The configuration parameter *gdActionPointOffset* [4] defines the action point offset from start of the slot in macroticks. Values can range between 1 and 15 macroticks [4]. It defines the minimum *Idle* period between two consecutive data frames. The value of *gdActionPointOffset* depends mainly on the maximum propagation delay within the system. The minimum required value for *gdActionPointOffset* can be calculated as follows [4]:

$$gdActionPointOffset[MT] \geq 2 \times gOffsetCorrectionOut[MT] -$$
$$\min\left(\left\{x \middle| x = floor\left(pDelayCompensation[uT] / MicroPerMacro[uT/MT]\right) \textit{ for each node and channel}\right\}\right)$$

## 10. REFERENCES

[1] Preliminary Device Specification TJA1080/N1A, Philips Semiconductors, 09-10-2003

[2] FlexRay Electrical Physical Layer Specification V1.4.5, FlexRay Consortium, 04-03-2004

[3] TJA1080 FlexRay Bus Driver – First Silicon Engineering Samples, Functional Evaluation Results, Technical Note, 21-01-2004

[4] FlexRay Protocol Specification V1.0, FlexRay Consortium, 30-09-2003

[5] MIL-STD-883, Method 3015, Electrostatic Discharge Sensitivity Classification

# 11. APPENDIX

## 11.1 Acronyms and abbreviations

| | |
|---|---|
| BD | Bus Driver |
| BG | Bus Guardian |
| BSS | Byte Start Sequence |
| CC | Communication Controller |
| CHI | Controller Host Interface |
| ECU | Electronic Control Unit |
| EMC | Electromagnetic Compatibility |
| NIT | Network Idle Time |
| TDMA | Time Division Multiple Access |
| TSS | Transmission Start Sequence |
| WU | Wakeup |
| WUS | Wakeup Symbol |

## 11.2 Technical Notes on first silicon TJA1080 version (N1A)

The evaluation of TJA1080 first silicon engineering samples [3] has revealed some deviations from the preliminary product specification, which are summarized in Table 11-1. All identified deviations are addressed during redesign.

| DESCRIPTION | REMARK |
|---|---|
| **In both configurations (Node and Star)** | |
| Receiver delay (tD(BUS-RXD)) is longer than expected | |
| Bus error flag can be erroneously set by VBAT start-up or transmission | |
| Status register cannot be read when there is a VBAT or Vcc undervoltage condition | |
| RXEN reacts slower than specified on bus activity | |
| No pull-down current at STBN and EN | Ensure that STBN and EN are not floating at any time |
| **In node configuration** | |
| INH1 does not become floating in Sleep mode | Use only INH2 |
| **In star configuration** | |
| Star-locked → Star-sleep transition is not possible as TRXD does not switch to Idle in Star-locked state | |
| If no proper FlexRay frames are applied (particularly if TSS is not received with 3 or more bits) → Star configuration only works for data rates up to 6.5Mbit/s | Star configuration works as desired up to 10Mbit/s if proper FlexRay frames are applied (TSS is received with 3 or more bits) |

Table 11-1: Evaluation results of first silicon engineering samples