AH1203

Application Hints - Partial Networking

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Document information

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Summary

This application hints document explains the basics of partial networking and its motivation. It explains the selective wake-up functionality as implemented in the standalone high speed CAN transceivers TJA1145 and TJA1145/FD, as well as in the mini high-speed CAN System Basis Chip UJA1168 (including product variants).

This information supports ECU hardware and software designers in the creation of applications incorporating partial networking in CAN networks.

Revision history

Rev	Date	Description
01.00	2013-02-22	Initial version
01.01	2013-08-07	Update of chapter “Autosar / Software driver”

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1. Introduction to Partial Networking

1.1 Partial Networking

Partial networking is the ability of a network to allow a subset of nodes to actively communicate, while the remainder is inactive and in a low-power mode, watching the bus traffic for so called “wake-up frames” (WUFs).

Upon correct reception of a WUF, the node’s transceiver can activate the entire node. WUFs are sent by active nodes in the network in order to “wake-up” other inactive nodes to enable certain functions in the CAN network which are used from time to time only. Such WUFs may address nodes individually or as a group. This allows the transceivers of non-addressed nodes that receive the wake-up frame to ignore it and keep the entire ECU in a low-power state.

The functionality is called “selective wake-up” and standardized in the industry standard ISO11898-6.

The decision to stop active communication and enter a low power mode with selective wake-up function enabled needs to be made on application software level and is thus controlled by the microcontroller and not by the transceiver.

1.2 ISO11898-6: a new standard for Partial Networking

Part 6 of the ISO11898 standard is defining the selective wake-up function for CAN bus systems. The selective wake-up function is fully implemented in the CAN transceiver, thus only the transceiver part of the node needs to be powered with minimum supply current to watch out for a valid WUF. The rest of the node (e.g. the microcontroller) can be completely unpowered.

Today’s standard high-speed CAN transceivers according to ISO11898-5, like the TJA1043 from NXP, will wake-up when any traffic is detected on the bus. This results in all nodes in the network being awoken, even if just a few nodes of a network are communicating during a certain phase of vehicle operation.

1.3 Innovative factor of implementing Partial Networking

Partial networking enables ECU designers to go an innovative step with existing and new ECU designs because it addresses the following advantages:

Power saving / Reducing CO_2:

Unused ECUs can be set to Sleep Mode with the selective wake-up function enabled, instead of being idle and draining power. Each node in Sleep Mode saves additional power and consequently reduces the CO_2 emission of the car. This is especially relevant for driver assistance and comfort ECUs that do not need to react within a few milliseconds, for example seat heating, rear view cameras, so on.

Reducing wake-up lines and relays:

Many CAN networks are already switching off unused modules via a relay that disconnects the battery supply. Another often used approach is deactivation by a dedicated CAN message and reactivation via a signal on a dedicated wake-up line. Both solutions require extra wires to be routed through the car, which gives additional cost, weight and inflexibility. Partial networking allows a significant reduction of these additional wake-up lines and relays and offers a maximum of flexibility.

Reducing the ECUs operating and up time:

The ability to have the ECU (except for the transceiver) unpowered when in partial networking Sleep Mode reduces the up time of voltage regulators, capacitors, microcontrollers and all other components in the module. This is of high advantage especially in hybrid and electric vehicles, where the battery charging time adds to the driving cycle. By use of partial networking, there is the potential to avoid specifying longer active times for ECUs that do not need to take part in the CAN communication while the vehicle battery gets charged.

2. Power consumption and power saving potential

The power consumption of a node is a highly important topic, especially with EU legislation specifying one-time fees to be paid by vehicle manufacturers if CO_2 limits are exceeded. Even just listening to the CAN bus, can consume a significant amount of electrical energy (easily in the range of 100mA), irrespective of the power consumption of its actual function. In larger networks, this effect can be multiplied to a significant number.

By contrast, NXP’s TJA1145 and UJA1168 consume less than 1mA while waiting for a WUF. Partial Networking also ensures that nodes which aren’t addressed in typical communication are kept in Standby or Sleep mode for longer, maximizing the energy saving potential. Some car makers have demonstrated results of their investigations that show a power saving potential that turns into a CO_2 saving potential of 1… 2 g/km (see [10]).

The selective wake-up function can be used in Standby and also in Sleep mode. The Standby mode offers the possibility to keep a microcontroller and its RAM powered (and concurrently being in stop mode), which allows much faster reactivation compared to the Sleep mode, where the microcontroller is expected to be unpowered. Consequently, the power saving potential in Standby mode is less compared to the Sleep mode, for the sake of faster reactivation.

Finally a node likely can change from Standby to Sleep mode in case the CAN bus traffic stops completely, when also all other nodes entering Sleep or Standby mode. As the application software which decides the nodes’ mode changes is inactive when in Standby mode, the TJA1145 and UJA1168 can additionally generate a wake-up event in case the bus becomes idle, which allows the microcontroller to change the ECUs operating mode accordingly. For details see chapter 8 “CAN bus silent event”.

3. Selective wake-up function

3.1 Supported bit rates

The selective wake-up function of a transceiver requires configuration of the transceiver to support the used CAN bus speed. In order to keep the configuration as simple and reliable as possible only a set of discrete CAN bus speeds are supported:

50kbps, 100kbps, 125 kbps, 250 kbps, 500 kbps and 1 Mbps

Configuration of the devices for a dedicated bus speed is done by selecting the CAN data rate in the Data Rate Register (0x26). The power-on default value is 500kBit/s.

3.2 Required bit timing on the CAN bus

Loss of arbitration scenarios and sender clock deviations need to be considered, when partial networking is used. The transceivers capabilities to decode CAN frames might have stricter limits as those of a microcontroller as the transceiver does not have a precise clock source like a crystal; it relies on in internal clock source. ISO11898-6 requires a certain tolerance to bit timing deviations resulting from loss of arbitration and sender clock tolerances.

The NXP products are exceeding the tolerable bit timing deviations required by the ISO11898-6 by far for bit rates below 1Mbps, thus offer much more flexibility in network designs. Consequently, the NXP products are less sensitive to bit time tolerances compared to devices that just fulfill the ISO standard.

To ensure CAN frames are decoded correctly, the following bit timing requirements need to be met:

1. The sender clock tolerance shall not exceed 0.5%
2. The maximum arbitration jump width shall not exceed 67.5% of a bit time (55% at 1Mbps)
3. The ringing at the end of a dominant bit shall not exceed 67.5% of a bit time (55% at 1Mbps)
4. The “ringing at the end of a dominant bit” plus “arbitration jump width” shall not exceed 90% of the bit time (70% at 1Mbps)

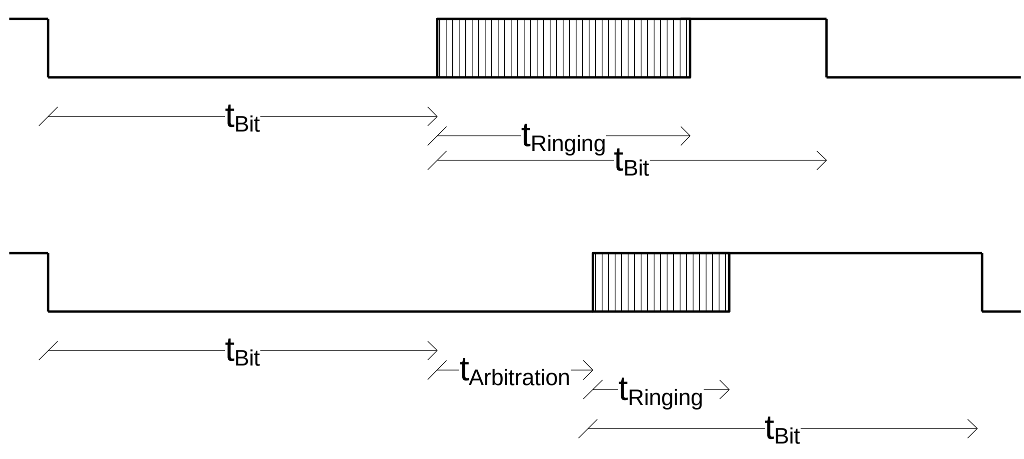

Figure 1. Bit timings

4. Configuration of partial networking

4.1 Introduction

Partial networking is the concept of splitting the network in sub-networks that can be separately woken-up by dedicated wake-up frames (WUFs). Such sub-networks may comprise any number of nodes, even including only one node or all nodes on the network. A node may belong to more than one sub-network. A strategy needs to be defined how this selective wake-up of the sub-networks by WUFs shall be handled.

A WUF is a standard CAN frame according to ISO11898-1 and thus consists of the CAN Identifier (Standard of Extended Format), the Data Length Code and the Data Field of a CAN frame. Depending on the configuration, all of these elements can be used to control the wake-up of sub-networks. Furthermore a frame on the bus needs to be free of CRC, stuff and form errors to be a valid WUF. Any error after the CRC delimiter is ignored and does not invalidate a received WUF.

4.2 ID and ID mask

The identifiers (IDs) of CAN messages that have the possibility to wake-up sub-networks need to be defined within the transceiver configuration.

The bit IDE (**ID**entifier **E**xtension) in the frame control register (0x2F), determines whether WUFs have 11bit standard IDs (IDE=0) or 29bit extended IDs (IDE=1).

In case 11-bit standard ID (or IDs) are used for wake-up, the ID register0 and ID register1 are not used; the values stored there are “don’t care”.

If there is only one CAN ID that is used for a wake-up, then this ID needs to be programmed into the ID registers of the device and all ID mask registers shall be set to 0x00. The ID mask registers are used to exclude certain bits from the comparison of the received ID with the ID stored in the ID registers. This can be used if, e.g. several frames shall lead to a bus wake-up.

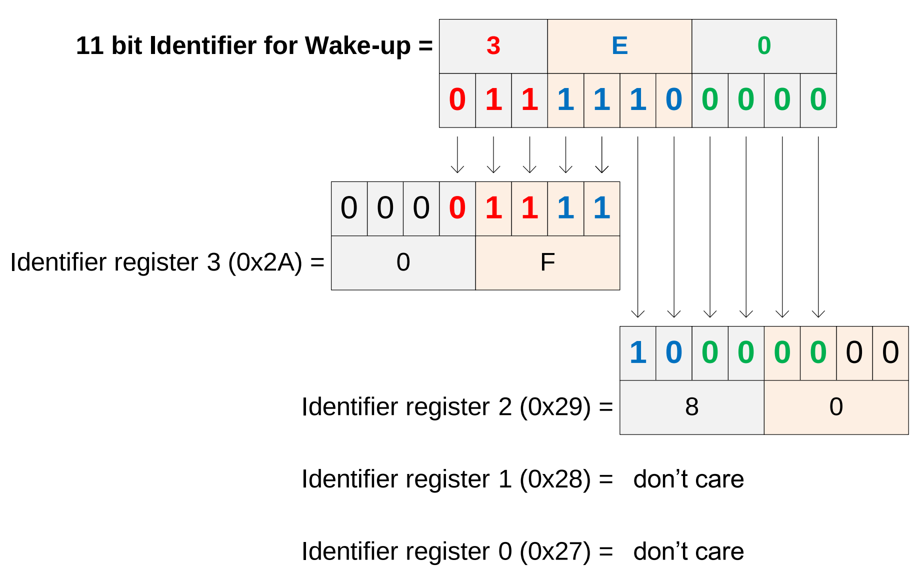

Figure 2. Example how to configure a 11 bit ID

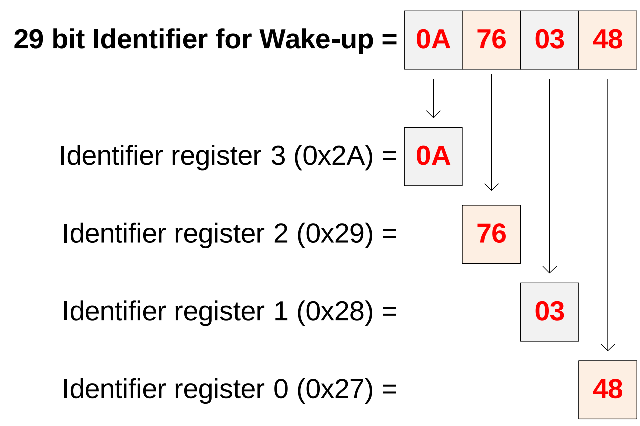

Figure 3. Example how to configure a 29 bit ID

If more than one CAN identifier is used to wake-up, then the ID mask has to be configured accordingly. The following example illustrates this:

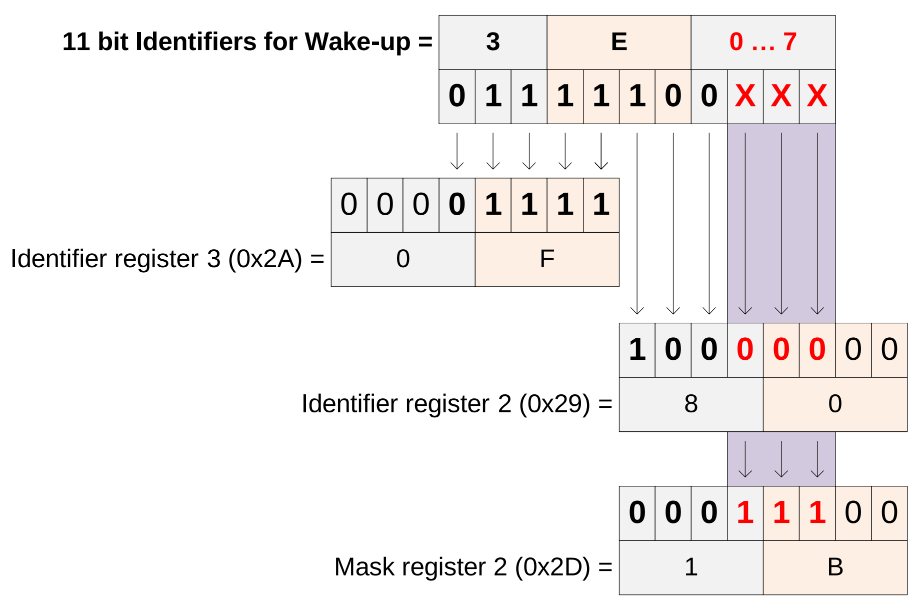

Figure 4. Example how to configure a range of 29 bit IDs

Logic “1” within the Identifier Mask register sets the corresponding Identifier bit position to “don’t care”. The power-on default value in all ID mask registers is 0x00.

4.3 Data mask bit

If the TJA1145 or UJA1168 should wake-up only when the received identifier matches the configured identifier (or range of identifiers), the data of the received frame does not need to be considered. In this case, the **P**artial **N**etworking **D**ata **M**ask bit (bit PNDM in the frame control register 0x2F) needs to be set to zero. In this case, so-called remote frames (CAN frames with RTR=1, see ISO11898-1) can also be used for waking-up. No further configuration is necessary in this case.

If the wake-up should occur only when the received identifier and data length code matches and a defined bit in the data field is set (see section 4.5 “Data field configuration”), then the PNDM bit has to be set and further configuration is necessary. This configuration is described in the following two sections. With the PNDM bit set, remote frames are no longer valid wake-up frames.

Note that a frame with CAN FD frame format can never be a WUF, even when PNDM=0.

4.4 Data length code configuration

If PNDM=1, the received data length code should match the data length code, as configured in the DLC bits in the frame control register.

Data length codes greater than 8 can be configured, even though only 8 bytes of data are expected to be received in this case. This means a frame can be sent with DLC=9 when it shall cause a wake-up and with DLC=8 in case it shall only transport its data without waking other nodes (in any case 8 data bytes are transmitted).

Note: ISO11898-1 requires that a CAN controller sends only 8 bytes of data, even when the DLC is set to values higher than 8.

Note: This method to mark a message as WUF with a DLC > 8 might not be useable in case you are using SW tools for configuration of the CAN communication, as those tools might decided to instantiate two messages with DLC ≤ 8 in case DLC > 8 is configured.

4.5 Data field configuration

The bits in the data field are also used to select the sub-networks to be woken-up. In contrast to the identifier and DLC field, where all bits have to match, the data field just requires one (or more) bits to match a configured “1”. Each Data Mask Register Bit, which is set to “1” would lead to a wake-up, if the received CAN Frame shows at that bit position a logic”1”, while of course the Identifier and DLC are matching as well to the frame.

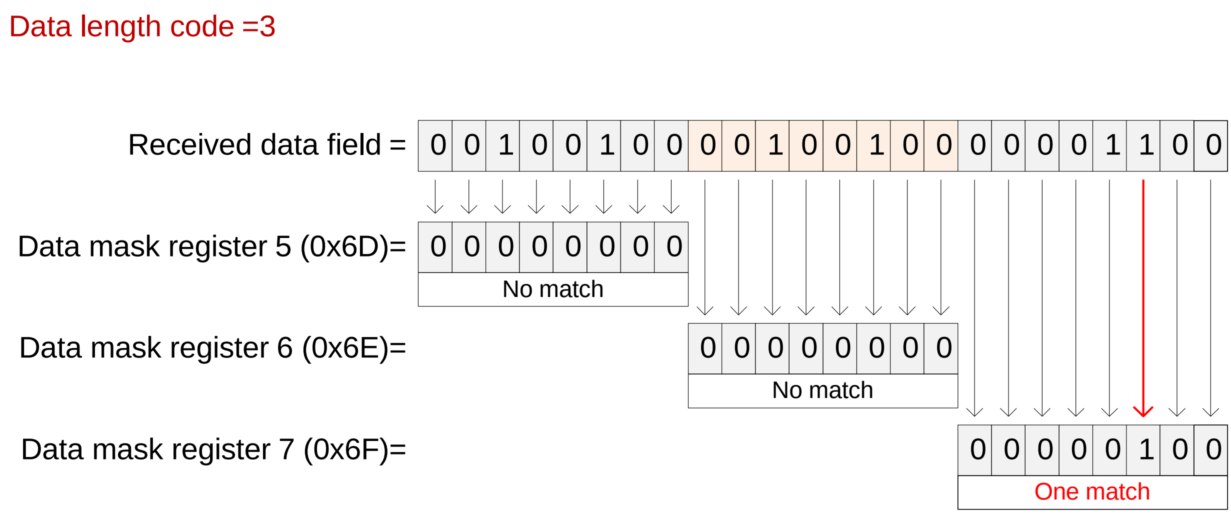

Figure 5. Example how to configure the data mask registers

The received data field shown in Figure 5 has in total 6 bits set and thus can wake-up 6 groups of nodes concurrently. Each bit in the data field is assigned to a functional group, while a transceiver or SBC is assigned to one or more sub-networks by configuring the corresponding Data Mask Register Bits to “1”. In the example above, the transceiver is just assigned to one sub-network, as seen in Data Mask Register 7.

4.6 Completing the configuration

To avoid entering Standby or Sleep mode with incomplete or incorrect register settings, the “**P**artial **N**etworking **C**onfiguration **OK**” bit (PNCOK in the CAN control register) has to be set each time the configuration registers have been set or altered.

If PNCOK is not set, the selective wake-up function cannot be enabled and wake-up occurs according to ISO11898-5 with any traffic on the bus. Additionally, any change in the configuration registers will automatically clear the PNCOK bit and disable the selective wake-up function.

The application should read back the configuration before setting PNCOK.

4.7 Enabling selective wake-up function

Selective wake-up is enabled by setting the “**C**AN **P**artial **N**etworking **C**ontrol” (CPNC) bit in the CAN control register. Further settings that are needed are PNCOK=1 (see section 4.6) and CWE=1 (CAN Wake Enable).

4.8 Enabling CAN FD tolerance

The TJA1145/FD, UJA1168/FD and UJA1168/VX/FD offer a CAN FD passive function, which allows transceivers to ignore frames in CAN FD frame format. This allows the device to remain in Standby/Sleep mode with selective wake-up function enabled during CAN FD communication, with no error reporting. The CAN FD passive function is enabled by setting the **C**AN **FD C**ontrol (CFDC) bit in frame control register.

In case the CFDC bit is not set, or the device is not equipped with the CAN FD passive feature, the CAN decoder in the transceiver waiting for the WUF will increase its frame error counter with reception of each CAN FD frame, due to it being incompatible with the standard CAN frame format. Upon error counter overflow, the device will wake-up.

4.9 Fail safe feature

In case the TJA1145 or UJA1168 is forced to Sleep mode due to under voltage conditions, the selective wake-up function is automatically deactivated (CPNC is cleared). This is done to ensure fast recovery to normal operation after such under voltage and avoid the need to wait for a valid WUF to occur on the bus.

4.10 Configuration Flow Checklist

This section provides a short check list that also can be used as guidance for a configuration flow:

1. Should 11-bit or 29-bit IDs be used for the wake-up frame (WUF)?
   If 11-bit, then set IDE=0, else set IDE=1.
2. Should wake-up already occur on a matching ID?
   If YES, then set PNDM=0 and continue on to step 6.
   If NO, then the DLC will also have to match and the data field will be evaluated. Set PNDM=1.
3. Set the DLC to the DLC that the desired WUF will have.
4. Set the ID and ID mask registers to match the desired WUFs IDs.
5. Set the Data Mask registers to assign the node to the chosen wake-up groups.
6. If CAN FD passive function should be enabled, set CFDC=1 (TJA1145/FD, UJA1168/FD and UJA1168/VX/FD only)
7. Read back the configuration and verify that the registers are set as expected
8. Set PNCOK=1 to confirm that the configuration registers are set correctly

5. Wiring harness

The CAN bus wiring harness does not need to be changed when partial networking is introduced. If for certain reasons wake-up lines or switched battery supplies have been used in the past, then these become obsolete with partial networking. This saves weight, costs and increases the flexibility as changes in the sub-networks configuration can be done via software only.

6. Uptime reduction by partial networking

Partial networking means also the uptime of microcontrollers and power supplies are reduced, since in partial networking Sleep mode only the TJA1145 or UJA1168 is powered.

For the background of electric and hybrid vehicles where CAN communication is active additionally to the drive phase also in the battery charging hours, partial networking is an attractive means to keep uptimes low.

7. Reaction time for selective wake-up

7.1 After bus idle

After bus idle, the TJA1145 / UJA1168 needs to receive one single CAN frame to start activating the bus bias (see chapter 10) and CAN decoder. The latter needs at most 300µs to become active. Assuming that all ECUs are in Sleep none can send a dominant acknowledge bit, thus the sending ECU keeps repeating the message until at least one ECU has woken-up, activated its CAN channel and given an acknowledge.

This means that the wake-up time for an ECU with partial networking compared to an ECU without partial networking is, in the worst case, “300µs + 1 CAN frame” longer.

For TJA1145 / UJA1168 this timing is also valid in case there is silence on the bus during this 300µs period; e.g. due to “transmit cancellation”.

7.2 While bus active

While the bus is active, the devices keep the CAN decoder active. The reaction time (RXD pulled low, INH pulled high) after CRC delimiter of the WUF is around 8µs.

8. CAN bus silent event

The selective wake-up function can be used in Standby and also in Sleep mode. The Standby mode offers the possibility to keep a microcontroller powered (and concurrently in stop mode), which allows much faster reactivation compared to the Sleep mode in which the microcontroller is expected to be unpowered.

Finally, a node likely can change from Standby to Sleep mode in case the CAN bus traffic stops completely, when also all other nodes entering Sleep or Standby mode. As the application software that needs to decide about the node’s mode changes is inactive in Standby, the TJA1145 / UJA1168 can generate a wake-up event in case the bus becomes idle. The CAN Bus Silent Event is signaled by the “Can Bus Silent” bit CBS in the Transceiver event status register. Generation of this Event is enabled by CBSE and the current status of the bus can be retrieved by reading the “**C**an **B**us **S**ilent **S**tatus” bit CBSS.

9. Software flow: Go to Sleep

To send a node into partial network Sleep mode during active CAN-bus traffic, the following workflow and described sequence (according to figure 6, see next page) is recommended:

1. Configuration of wake-up frame in the transceiver.
   This may be done at any earlier stage as well (e.g. power-up phase).
2. Enable selective wake-up function of the transceiver.
   This can also be done directly after wake-up frame configuration.
   From now on all wake-up frames can be identified and the flag CW (CAN wake-up) will be set upon the reception of a frame that meets the definition of a WUF for this transceiver.
3. Reset the CW flag in the transceiver, if it has already been set previously.
4. Switch off the CAN protocol controller in the microcontroller – it remains unreceptive and ignores signals on the RXD input. Bus traffic remains visible on RXD input.
5. Switch transceiver from *normal* mode into *Standby* mode. Even though there is active bus traffic, RXD now remains recessive until a valid wake-up frame is identified (selective wake-up).
6. The wake-up function of the CAN protocol controller in the µC needs to be activated now to ensure that a wake-up signaled by the transceiver to RXD will be identified.
7. Read the **C**AN **W**ake flag ‘CW’.
   If the flag is set: reactivate CAN protocol controller (because there was a relevant wake-up event during the transition phase to Low Power).
   If flag is not set: shut down power supply – the node enters *Sleep* mode.

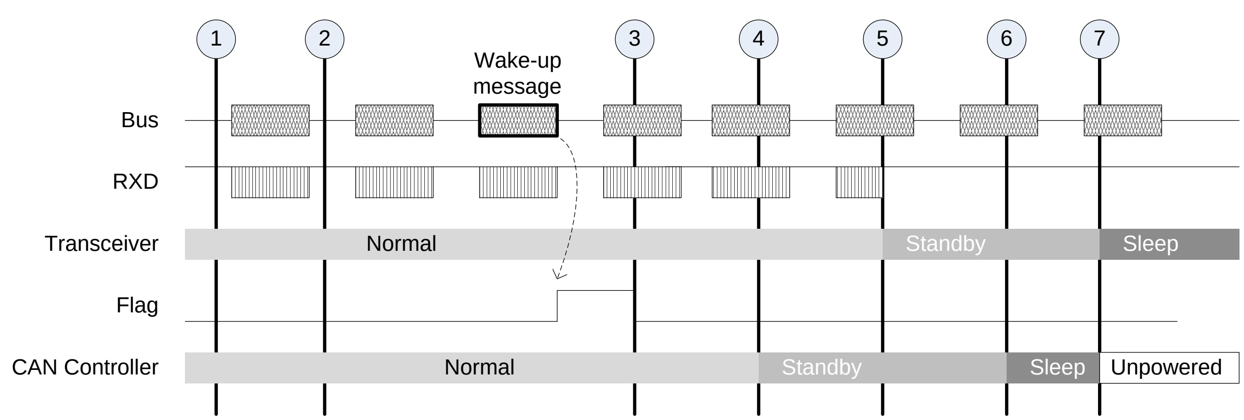

Figure 6. Transition to partial network – Sleep mode

Further details about software implementation and example flows are explained in the NXP application hint documents

- **High speed CAN transceiver for partial networking TJA1145 [4].**
- **Mini high speed CAN system basis chips UJA1163 / UJA1164 / UJA1167 / UJA1168 [5].**

10. Automatic voltage biasing / Auto bias

Transceivers and system basis chips according to ISO11898-6 have to support the so called “automatic voltage biasing”. This means that the device does only terminate its bus-pins to ground while being in a low-power mode and the bus being idle for longer than approximately 1s, otherwise the bus is biased towards 2.5V, see figure 7 on the next page.

Devices according to ISO11898-5 always terminate their bus pins to ground when in low power mode.

The bus is considered not to be idle, when a dominant-recessive-dominant sequence has been received that fits the timing requirements for wake-up according to ISO11898-5.

This function has been introduced to avoid that nodes in low-power mode do increase the electromagnetic emission of the communication system by pulling the common mode voltage down during idle, enforcing a common mode step with each dominant bit on the bus.

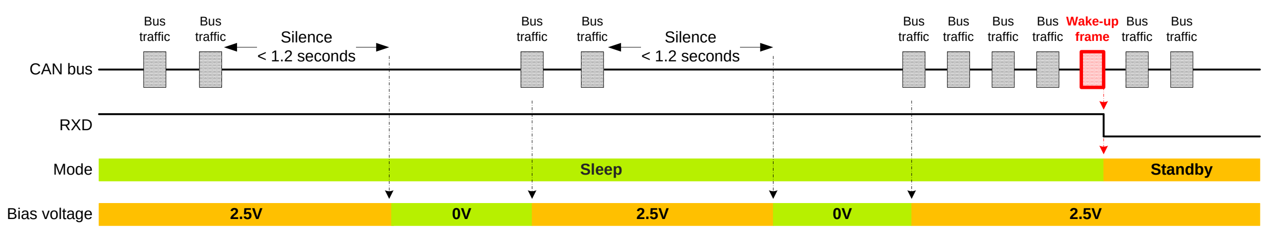

Figure 7. Autonomous bus biasing

11. Autosar / Software driver

Partial networking functionality is supported by Autosar. The concepts have been introduced with Autosar version 3.2.1.

The Autosar “Specification of CAN Transceiver Driver” proposes sequences how to change operation modes. A general flow for entering Sleep mode while other modules remain active is also described in this document in chapter 9.

An Autosar v3.2.1 conformant software driver for NXP's TJA1145 is licensed by NXP and available at the Vector Group (www.vector.com).

Contact details: embedded@de.vector.com

12. CAN FD and partial networking

12.1 Introduction

Selective wake-up according to ISO11898-6 requires that transceivers are able to decode CAN frames as described above.

In 2012 Bosch proposed a new frame format called CAN FD frames that allow more than 8 bytes of data per frame and moreover allows a higher bit rate in the data field than in the arbitration field. Obviously this is not backward compatible to ISO11898-1 and thus CAN FD frames cannot be decoded by partial networking transceivers.

Moreover reception of CAN FD frames will result in a decoding error, which in turn increases the partial networking frame error counter in the transceivers. If this counter overflows at its 32nd increment, the transceiver wakes up. This function is required to avoid any dead-lock situation, if a transceiver with selective wake-up functionality would be configured with e.g. wrong baud rate settings or its internal oscillator frequency is out of specification.

12.2 CAN FD Passive feature

With CAN FD becoming an important topic for some in-vehicle networks, NXP has implemented an additional feature into the TJA1145/FD, UJA1168/FD and UJA1168/VX/FD products to allow them to behave passively when CAN FD communication is occurring on the bus. This CAN FD passive feature allows the node to remain in Sleep while CAN FD frames are transmitted on the bus, without increasing the frame error counter inside the transceiver. The devices can still be woken by ISO11898-1 compliant wake-up frame with the configured address.

This feature is activated only when the CFDC bit in the frame control register (address: 0x2F) is set.

This allows true operation of a network with a mixture of CAN and CAN FD nodes.

One use case for this feature is to set non-CAN FD enabled nodes to Sleep or Standby, while other CAN FD enabled nodes communicate by means of CAN FD frames. This can be advantageously used in special operation modes, for example FLASH memory download, diagnostics modes, etc, where high bit-rate communication is needed for only a sub-group of nodes.

12.3 CAN FD bit rates

For compatibility reasons, a CAN FD frame starts with the known identifier field of a ISO11898-1 CAN Frame and makes use of one of the reserved bits in the CAN protocol, to separate between the ISO11898-1 CAN formats and the new CAN FD format. Thus, up to that reserved bit, the CAN FD frame looks like a CAN frame.

Transceivers with the CAN FD passive feature will follow the CAN FD frame up to that point in the frame and detect the presence of a CAN FD frame, based on the reserved bit to be HIGH instead of the expected LOW level from a normal CAN frame. At this point, the transceiver will judge the frame as correct and ignore the rest of the frame.

12.3.1 Arbitration phase

The supported bit rates in the arbitration phase are consequently

50kbps, 100kbps, 125 kbps, 250 kbps, 500 kbps and 1 Mbps

The bit rate has to be configured in register 0x26 (data rate register).

12.3.2 Limitations in fast phase bit rates

The bit rate of the fast phase does not need to be configured. However, two limitations of the ratio between arbitration bit rate and fast phase bit rate need to be considered:

1. The bit rate in the fast phase needs to be equal or higher than the bit rate in the arbitration phase.
2. The bit rate in the fast phase must not exceed 8 times the bit rate of the arbitration phase. In case the bit rate in the fast phase is exceeding this limit false wake-ups might happen.

13. References

[1] Objective data sheet TJA1145, High speed CAN transceiver for partial networking – NXP Semiconductors, Rev. 00.16, 15 July 2013

[2] Product data sheet UJA1168, Mini high-speed CAN system basis chip for partial networking – NXP Semiconductors, Rev. 01.00, 5 August 2013

[3] Application Hints, Rules and recommendations for in-vehicle CAN networks, TR1135 – NXP Semiconductors, Rev. 00.01, 24 September 2012

[4] Application Hints, High speed CAN transceiver for partial networking TJA1145, NXP Semiconductors, *"under construction"*, 2013

[5] Application Hints, Mini high speed CAN system basis chips UJA1163 / UJA1164 / UJA1167 / UJA1168, NXP Semiconductors, Rev. 01.01, 4 June 2013

[6] Road Vehicles – Controller Area Network (CAN) – Part 1: Data link layer and physical signaling, ISO11898-1, International Standardization Organisation

[7] Road Vehicles – Controller Area Network (CAN) – Part 2: High-speed medium access unit, ISO 11898-2, International Standardization Organisation

[8] Road Vehicles – Controller Area Network (CAN) – Part 5: High-speed medium access unit with low power mode, ISO 11898-5, International Standardization Organisation

[9] Road Vehicles – Controller Area Network (CAN) – Part 6: High-speed medium access unit with selective wake-up functionality, ISO 11898-6, International Standardization Organisation

[10] "Reduktion des Stromverbrauchs des Kommunikationsnetzes durch Teilnetzbetrieb" 2. GMM-Fachtagung "Automotive meets Electronics", May 4+5, 2011, Westfalenhalle Dortmund (www.ame2011.de)]

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