The new wake-up pattern for a robust system

Magnus-Maria Hell, Infineon

As CAN was developed 30 years ago, the CAN bus was used in automotive applications only. The CAN bus was active in driving mode. New features, such as keyless entry require permanently supplied ECUs, which must be activated via CAN bus. This article describes how to wake up a transceiver with one or more CAN frames very fast.

Transceivers with remote wake up feature have been on the market for 15 years. The first wake up method was specified in ISO11898-5:2007. In the field, unwanted wake up events caused by spikes or disturbance or a permanent short circuit on the bus were observed.
ISO 11898-2:2016 specifies the new wake up method, which reduces unwanted wake up events. The following sections describe:

- the established wake-up method
- the new wake-up method, based on WUP (Wake-up Pattern)

The established wake up method

ISO 11898-5:2007 has described remote wake up behavior for the first time. One or multiple consecutive dominant bus levels for at least t_{Filter}, each of them separated by a recessive bus level, trigger a bus wake up. t_{Filter} is specified from 500 ns to 5 μs. This is the range for the filter timing inside the transceiver. The information for the user of CAN networks is:

- A dominant bus level longer than 5 μs causes a wake up.
- A dominant bus level shorter than 500 ns is ignored.
- A dominant bus level between 500 ns and 5 μs may cause a wake up. t_{Filter} timing depends on the transceiver, which is used.

For bit rates up to 200 kBit/s (bit width longer than 5 μs), the dominant bus level condition is fulfilled with every dominant bit within a CAN frame. For bit rates up to 500 kBit/s the dominant condition is fulfilled for the classical CAN base frame format (CBFF) in the Control field with the RTR, IDE and r0 bit (ISO11898-1:2003) or RTR, IDE and FDF bit (ISO11898-1:2015).
All these bits are dominant and at 500 kBit/s (bit width=2 μs) the resulting dominant level is longer than 6 μs.

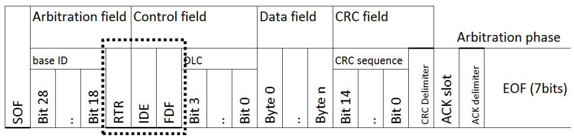

Figure 1: CBFF CAN frame

For the classical extended frame format (CEFF) the dominant condition is fulfilled in the Control field with the RTR, r1 and r0 bit (ISO11898-1:2003) or RTR, FDF and r0 bit (ISO11898-1:2015). All these bits are dominant and for example at 500 kBit/s (bit width=2 μs) the resulting dominant level is longer than 6 μs.

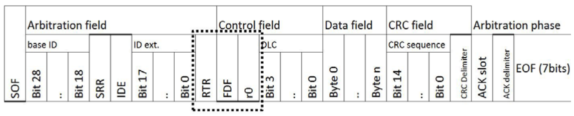

Figure 2: CEFF CAN frame

The condition for the recessive bus level in between is not specified.

Unwanted wake ups reactivate ECUs and discharge the battery in parking mode. One reason for unwanted wake ups are spikes coupled into the CAN bus. The drivers for dominant spikes on the bus are:

- Asymmetric coupled spikes into the bus
- Mode conversion (a recessive level on the bus will be converted to dominant during common mode)
- EMC or ESD pulses

The new robust wake-up pattern (WUP)

To improve the robustness the new WUP method was specified in ISO 11898-2:2016. The main differences are:

- Two consecutive dominant bus levels for at least t_{Filter}, separated by a recessive bus level of at least t_{Filter}, trigger a bus wake up.
- The same filter time t_{Filter} is specified for the recessive bus level in between two dominant levels
- The behavior in case of very long dominant or recessive bus level is defined.

Figure 3 shows the new wake up flow. After power on, the device jumps into state Ini. As long as the bus is recessive, the device in Ini state and dominant bus levels shorter than t_{Filter} will be ignored. With a dominant bus level longer than t_{Filter}, the device moves to state 1 and analyzes recessive bus levels. Recessive bus levels shorter than t_{Filter} and dominant bus levels will be ignored. If the recessive bus level is longer than t_{Filter}, then the device moves to state 2. Now, dominant bus levels shorter than t_{Filter} and recessive levels are ignored. If a dominant bus level is longer than t_{Filter} again, then the device changes into state 3 and wakes up. This wake up event is flagged on the RxD pin and/or on the Inhibit pin, if available. After the transceiver has detected a wake up, the ECU ramps up. In this phase the transceiver remains in low power mode and the transmitter is blocked to avoid any disturbance on the bus caused by undefined signals on the TxD (Transmit data) pin. After the ECU ramps up, the transceiver should be set into normal operating mode to receive and to transmit data.

After the remote wake up is detected, the transceiver toggles between state 3 and state 4, independent if the device is in lower power mode or in normal mode.

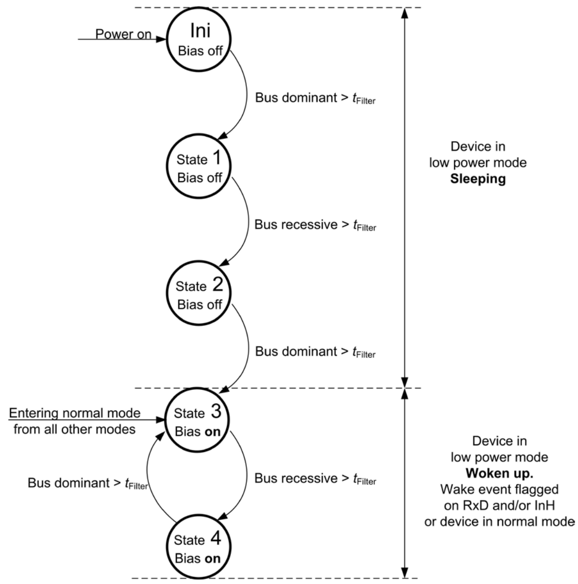

Figure 3: New Wake up Pattern flow

Figure 4 shows how this flow works in a CAN frame. In state **Ini** and state **2** the dominant levels shorter than t_{Filter} are ignored. In state **1** recessive bus levels shorter than t_{Filter} are ignored.

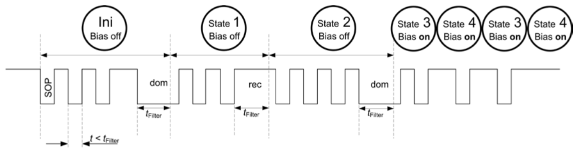

Figure 4: Wake up mechanism in a CAN frame

If the dominant bus level condition is fulfilled only once in a CAN frame, then the second CAN frame will wake up the device. The EOF/IFS field in between two CAN frames fulfills the recessive bus level conditions and the Control field the second dominant condition. Figure 5 shows this scenario.

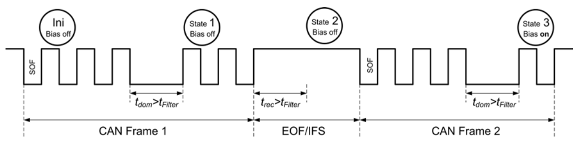

Figure 5: Wake up caused by two CAN frames

Worst case scenarios:

CANH shorted to battery

One cause for a permanent dominant bus level condition on the bus is a short circuit of CANH to battery. Depending on the number of nodes and the value of the input resistors of the transceiver used in the network, a short circuit of CANH to battery may cause a voltage drop at the termination resistor higher than 900 mV. In this situation, the transceiver changes to state 1. In state 1 a timer, called t_{Wake} timer, is started. To avoid an unwanted wake up after the recovery of the short circuit, the transceiver changes to state Wait after t_{Wake} timer expires (t_{Wake}). The transceiver remains in state WAIT as long as the bus is dominant and the transceiver will not wake up up. If the short circuit is removed and the bus level is recessive for longer than t_{Filter}, then the transceiver changes to state Ini. In state Ini the transceiver can wake up with the next CAN frame. Figure 6 shows this situation.

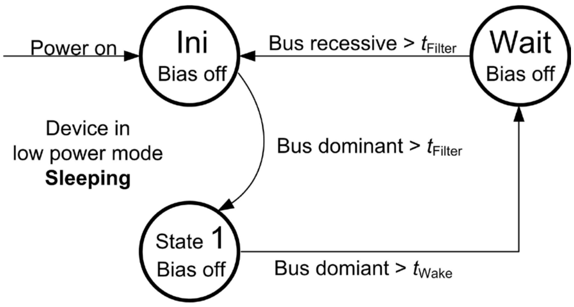

Figure 6: Flow for permanently dominant bus signal

The second worst case scenario is caused by a single spike on the bus, followed by a permanent recessive bus level. After a single spike the transceiver is in state 2. In state 2 the t_{Wake} is started. To avoid an unwanted wake up caused by a second spike, the transceiver changes to state Ini after t_{Wake} expires (see Figure 7). In state Ini the transceiver can wake up with a CAN frame. This solution improves the wake up feature for single spikes at a distance greater than t_{Wake}.

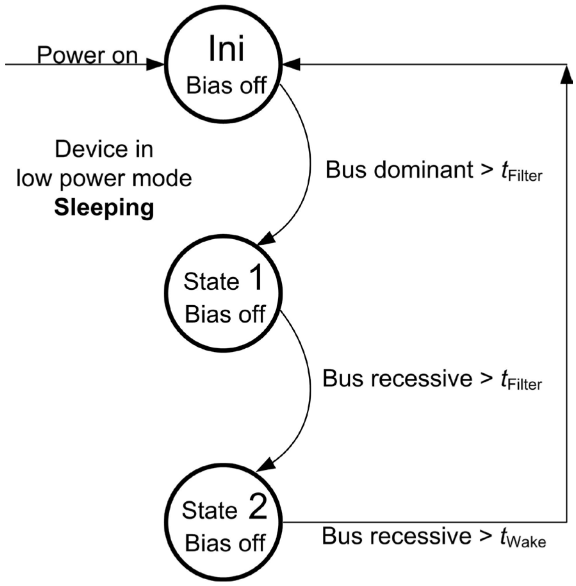

Figure 7: Permanent recessive level after a dominant spike

For injected pulses, according to ISO7637-2, the mechanism is robust. The distance between the pulses 1, 2a and 2b is longer than tWake and the duration of the pulses 3a and 3b

In state 3 the transceiver can be in low power mode or in normal operating mode. If the bus level is permanently dominant in low power mode, then the transceiver changes to state WAIT after the $t_{Silence}$ timer (> 1200 ms) expires. With a recessive bus level the transceiver enters state Ini (see figure 5).

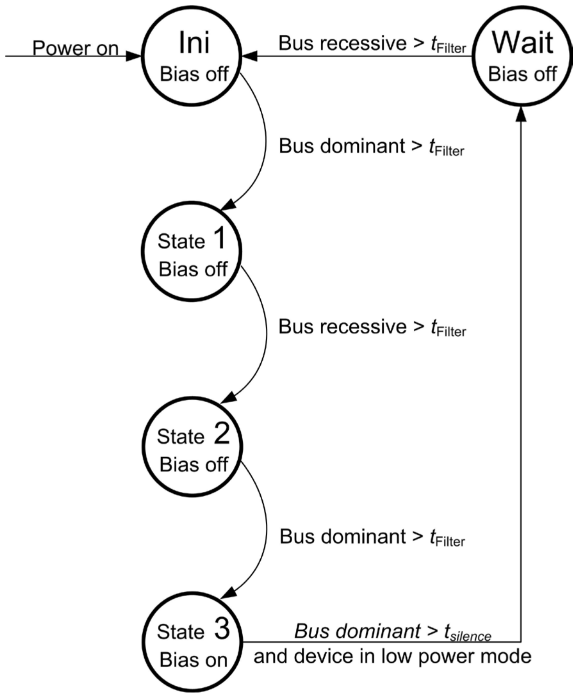

Figure 8: Permanent dominant level in State 3

Bus silence

If no communication is on the bus and the transceiver is in lower power mode, then the transceiver changes to State Ini after $t_{Silence}$ timer expires. After a transition from normal mode to low power mode, the wake up detection of the transceiver changes to state Ini, after $t_{Silence}$ timer expires. If the $t_{Silence}$ timer expires before the transition from normal to lower power mode, then the wake up detection directly changes to mode Ini. In normal mode the transceiver remains in state 4.

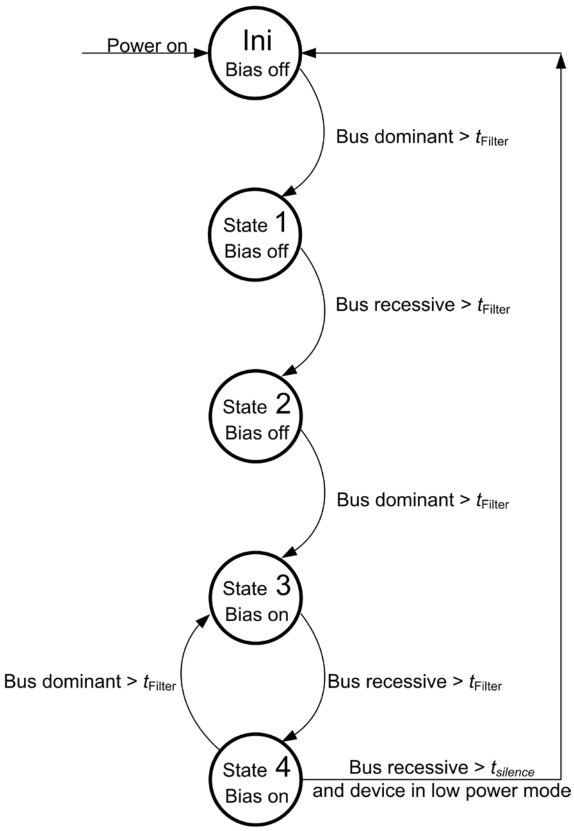

Figure 9: Permanent recessive level in State 4

The WUP and CAN FD

The Filter time t_{Filter} requires three consecutive dominant bits in a row. For classical CAN frames CBFF and CEFF this is guaranteed in the control field. For CAN FD frames with 11 Bit identifier (FBFF) two consecutive bits are specified (bit RRS and IDE, see Figure 9).

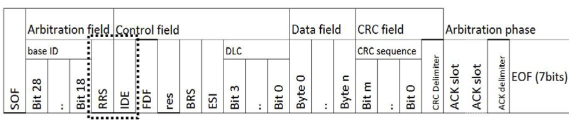

Figure 10: FBFF CAN Frame

For CAN FD frames with extended Identifier (FEFF) no consecutive dominant bits are specified.

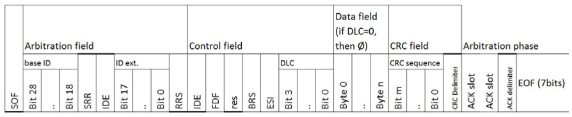

Figure 11: FEFF CAN frame

As a consequence reliable remote wake with CAN FD frames is not guaranteed with a filter time of maximum 5 μs. To ensure robust remote wake up also with CAN FD frames, ISO11898-2:2016 introduced a second tFilter time, called CAN activity filter time short. The maximum duration of this short filter time is specified at 1.8 μs, which is a little shorter than one bit time at 500 kBit/s (2 μs). As a consequence the minimum duration had to be fixed to 150 ns instead of 500 ns for the long filter time. This new short filter time ensures a reliable remote wake in CAN FD networks. However, sensitivity to spikes may increase. The wiring must be optimized to avoid mode conversion resulting in unwanted wake up.

Where is the bus level located?

Table 1 shows all relevant timings. These timings and the bus levels refer to the transceiver pins CANH and CANL. The timings and levels may vary in a network. All nodes of a network must meet these conditions to get a reliable and robust wake up.

Table 11 shows an overview of the relevant parameters for the new WUP method

Parameter	Notation	Min	Max	Unit
CAN activity filter time, long	t_{Filter}	0,5	5	μs
CAN activity filter time, short	t_{Filter}	0,15	1,8	μs
Wake up time	t_{wake}	0,8	10	ms
Time for bus inactivity	$t_{Silence}$	0,6	1,2	s

Conclusion

The new WUP method is expected to reduce unwanted wake up events. One step more, to prepare CAN physical layer for the next 30 years.

References

[1] ISO11898-1:2003, Road Vehicles – Controller Area network (CAN) – Part1: Data link layer and physical signaling
[2] ISO11898-1:2015, Road Vehicles – Controller Area network (CAN) – Part1: Data link layer and physical signaling
[3] ISO11898-2:2003, Road Vehicles – Controller Area network (CAN) – Part5: High-Speed medium access unit
[4] ISO11898-2:2016, Road Vehicles – Controller Area network (CAN) – Part5: High-Speed medium access unit with low power mode
[5] ISO11898-5:2016, Road Vehicles – Controller Area network (CAN) – Part5: High-Speed medium access unit with low power mode
[6] CiA 601-1: CAN FD node and system Design Part1: Physical interface implementation

Magnus-Maria Hell
Infineon Technologies
Am Campeon 1-12
DE-85579 Neubiberg
Tel.: +49-89-234-24003
Magnus-Maria.Hell@infineon.com
www.infineon.com