High Speed CAN

Specification

Requirements

Vehicle Manufacturers

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Version: 1.2

Audi AG, DaimlerChrysler AG, VW, Infineon, Motorola, Philips, TZ-Microelectronic
confirmed with BMW AG, PSA, ST-Microelectronics, c&s group

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1. Requirements

1.1. Task

- CAN high-speed Transceiver to be connected to permanent power

1.2. Basic Requirements

- Compliant to a 42 V permanent power system
- Compliant to a 12 V permanent power system
- operation cycle of a vehicle: > 5000h (5 V are available)
- live cycle of a vehicle: > 15 years (permanently connected to the battery)
- critical application: 150°C ambient, duration 25 h
- ambient temperature (→ heat-sink) -40 C° to + 125°C
- heat resistor Junction/heat-sink TBD
- state of the art:
  correct operation junction temperature to at least 150°C (test: 90000h at 150°C)
  10°C more will halve the operating duration
- baudrate: 100kBit/s to **1MBit/s**
- length of the transmission lines at 1MBit/s about 10m
- the number of ECUs[1] is not important for the bus driver
- loop-time[2] max.260ns. Target should be 225ns at 1MBit/s

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[1] at least 30 ECU has to be supported

[2] loop-time transceiver: delay from TX-edge → Bus → RX-edge
Conditions: C_{Rx} = 20 pF, $C_{CANH-GND} = C_{CANL-GND}$ = 100 pF, R_{Bus} = 60 Ω

System operating behavior						
Function		**min**	**typ**	**max**	**Unit**	**Remark**
Supply Voltage	VBat	0		4.7	V	no function required, neglectable input current
Supply voltage	VBat	4.7		42	V	whole operating functions[4]
Supply voltage	VBat	42		58	V	reduced operating functions due to e. g. thermal protection, any irreversible damage of the transceiver and of any connected module has to be avoided
Supply voltage	VBat	58			V	Any damage of the transceiver or of any connected module has not to be avoided. Any destruction of connected ECU (via the bus) should be avoided.

Table 1 proposal for the operation conditions

[4]the self protecting mechanisms of the transceiver are active and may influence its behaviour

1.3. Modes

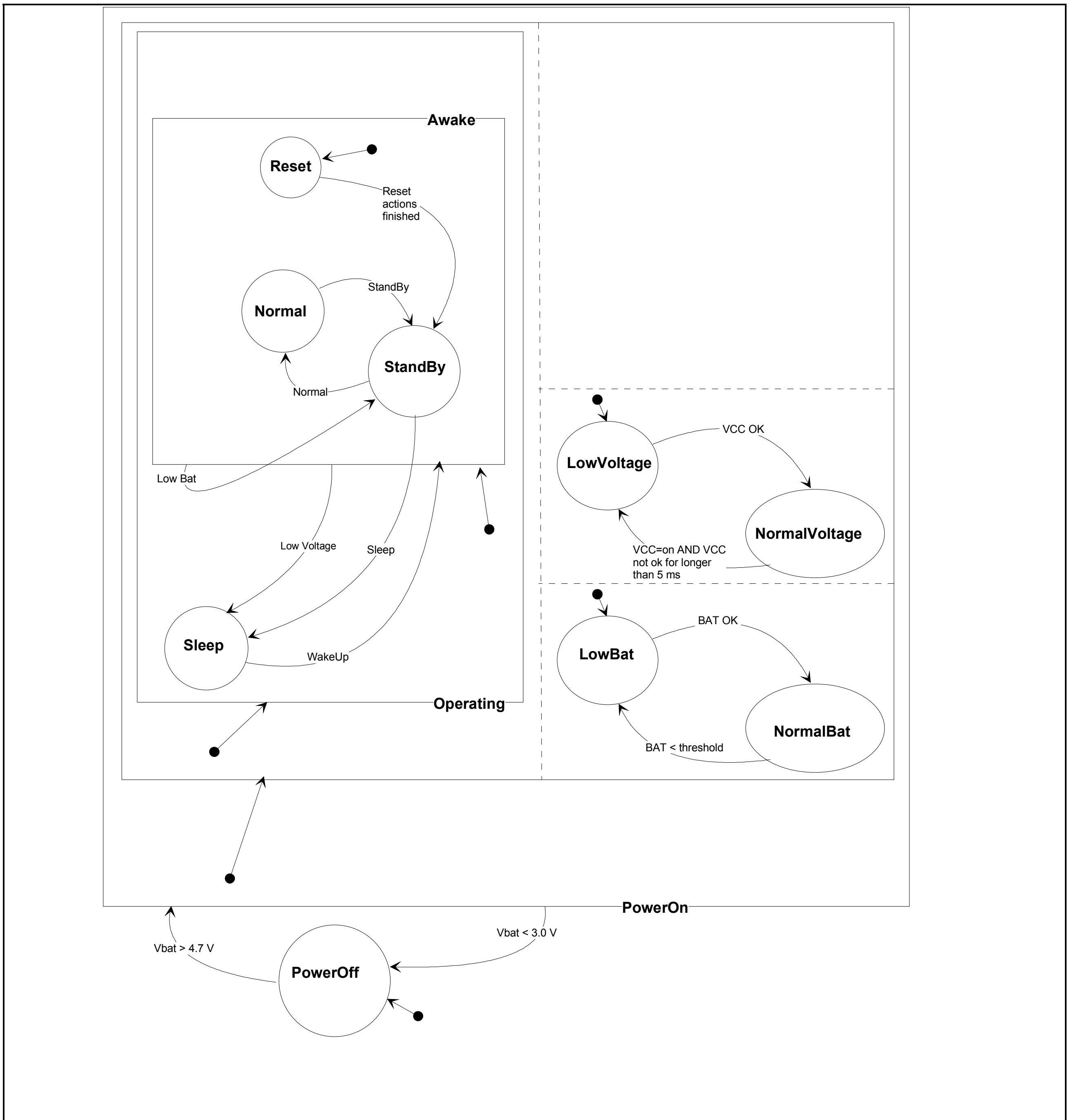

Figure 1 proposed simplified state transition chart
the fail silent behaviour has to be taken into account

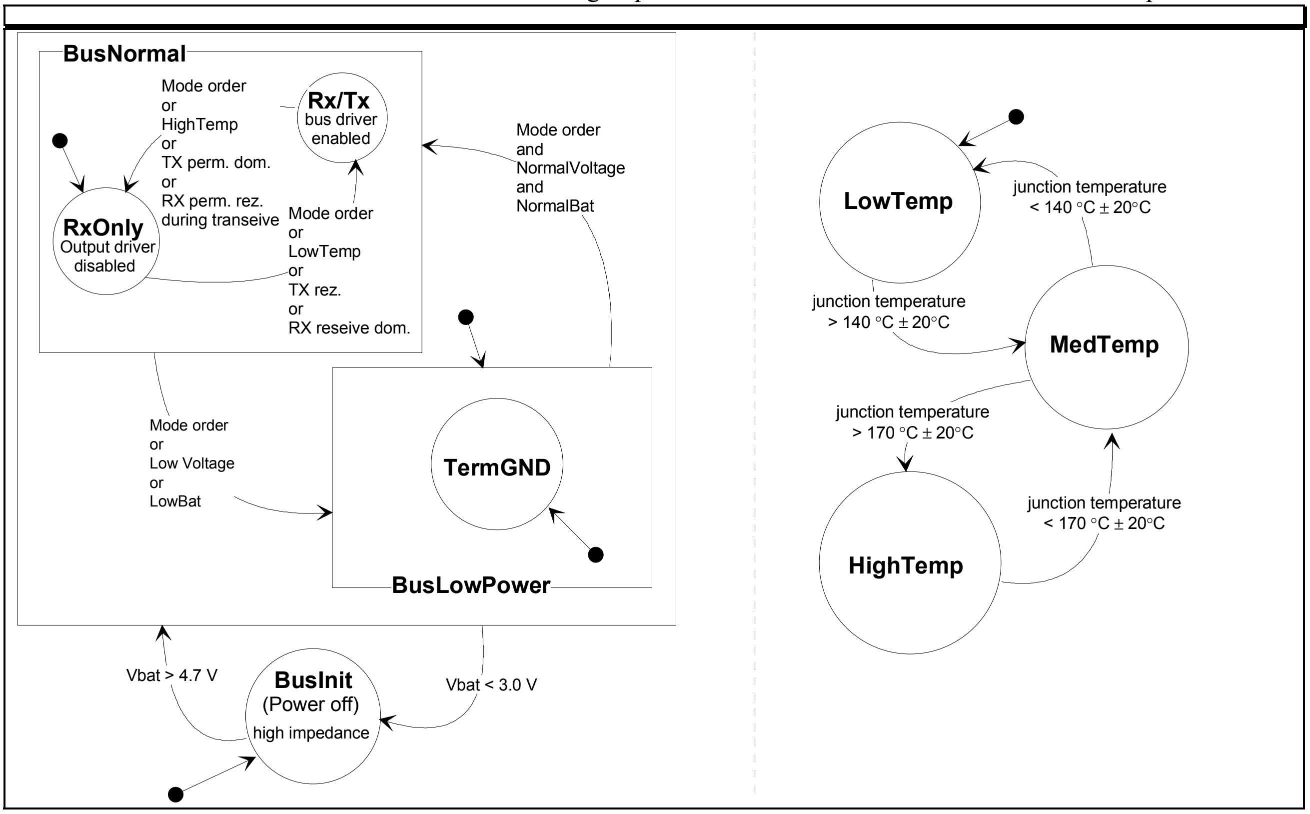

Figure 2 proposed simplified termination state transition chart
the fail silent behaviour has to be taken into account

1.3.1. Normal

- CAN driver active
- INH active (usually: voltage regulator active)
- VSPLIT active
- recessive termination active (2.5V)

Hint
- the mode “RxOnly” with an active receiver and an passive driver is hidden inside “Normal”

1.3.2. StandBy

- CAN driver <u>not</u> active
- INH active (usually: voltage regulator active)
- VSPLIT passive
- recessive termination active to GND

1.3.3. Sleep

- CAN driver not active
- INH passive (usually: voltage regulator not active)
- VSPLIT passive
- recessive termination active to ground

1.3.4. Transitions

The operation modes must be influenced by:

- at least one control pin
  → controlled by the µC
  → controlled by any signal (intern or extern the ECU) - it is required to connect an ECU-external wake-up signal to the bus driver

- signals from the bus
  standard messages or additional signals or levels

- fail silent behaviour

1.3.5. Wake-Up Detection

A wake-up via the bus-lines has to meet some requirements:

- a predefined row of "0" and "1" must be necessary to wake-up
  example: 500 kBit/s: rddxxx...
  1 MBit/s: rddddxxx...
  hint: the wake-up procedure has to meet the EMC requirements

- independent from the baud-rate

- nearly each valid message should be able to wake-up the transceiver

- the wake-up filter must ignore any common mode voltage on the bus lines

- the common mode range of the wake-up filter must be at least ±35 V

- passing the allowed common mode range may never wake-up the circuit

- the wake-up circuit may never behave like a amplitude de-modulator

1.3.5.1. Control Pin to the Voltage Regulator (very high priority)

Any voltage regulator must be controlled by the bus driver.

Reliability

It is strongly required to activate the INH-signal (usually: voltage regulator) just by passing additional plausible test. E. g. the INH may be activated only if a wake-up event has been recognised.

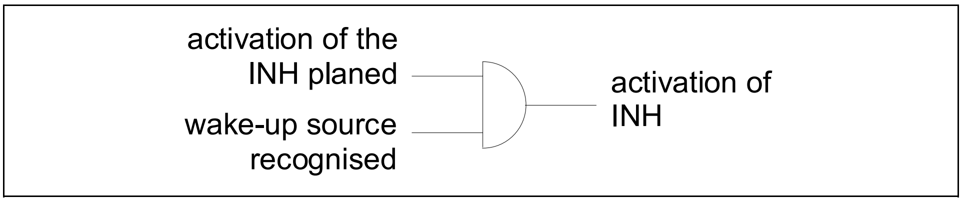

Figure 3

proposal to illustrate the increased reliability

1.4. Compatibility

1.4.1. Interoperability

Each vehicle manufacturer has different interoperability requirements. In the worst case the following bus-drivers will be used in any combination:

- CAN high-speed according the state of the art connected to the ignition (each supplier)
- CAN high-speed according the state of the art connected to permanent power (each supplier)
- new CAN high-speed connected to the ignition (each supplier)
- new CAN high-speed connected to permanent power (each supplier)

The functions of the poorest bus-driver must be supported in any combination.

1.4.2. 2nd Source

- 2nd source is strongly required
- 100% pin compliant
- 100% function compliant if following a user manual specific to each supplier

1.4.3. Line Levels

- compliant to the known ISO 11898 (high-speed) - during communication
→ common mode level of 2.5 V
- The levels of CAN_H and CAN_L have to be symmetrical against the termination voltage (2.5 V) during dominant states, the slew rates should be symmetrical within a tolerable difference of at least 10 %
- additional optional new levels are allowed

1.4.4. Termination

- to guarantee the interoperability to the ISO-11898 the bus lines have to be terminated to a fixed voltage (≈ 2.5 V)
- the bus lines has to be terminated to ground during low power mode
- if not powered (LowBat) the termination to ground has to be high impedence (≥ 500 kΩ see also 1.13.3. Reverse Current).

- several termination concepts has to be allowed (confirmed to the physically boundary conditions):
  → termination at the end of the transitions lines (VSPLIT connection optionally)
  → central termination in a star
  → distributed termination

1.5. Quiescence Current

- typically 20 µA[5] (very high priority) - wake up is monitored

1.6. EMC

- the transceiver has to work with and without a common mode choke

- EMC target specification: see GIFT/ICT activities

1.6.1. Electromagnetic Emission (EME)

- the results of the high-speed transceivers according the state of the art has to be met at least (without common mode coil).
- the emission should be independent from any ground shift in a networked system

1.6.2. Electromagnetic Immunity (EMI)

- the results of the high-speed transceivers according the state of the art has to be met at least

1.6.3. ESD

- at least 4 kV[6] human body model looking to the integrated circuit
- pins: see table 1

1.7. Ground Shift

- the results of the high-speed transceivers according the state of the art has to be met at least

1.8. Systems with 42 V

It is required to use the bus drivers inside vehicles with a 12 V[7] and a 42 V permanent power.

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[5] worst case 50 µA

[6] 8 kV should be reached

[7] perfect communication during a jump start is required (27 V DC in a 12 V permanent power system)

What can be expected in systems with 42 V

- 58 V DC at the permanent power pin
- 58V DC at the bus pins
- 58V DC at Wake up pins

Hint

- The vehicle manufacturers expect, that the standard 58V-process will fit the requirements the next few years

1.9. System

- ECUs connected to the ignition and to permanent power (12 V and/or 42 V) must work together at one net
- sub-net operation by RxOnly possible
  → a bypass during RxOnly (Tx → Rx) should not be implemented

1.10. Interface Bus Driver ⇔ µC

- µC supply voltage standards must be connectable (e. g. 3 V, 2.5 V, 1.8 V ...)
- 100% compatible among every supplier

1.10.1. Wake-Up Sources

- each wake-up event has to be signalled
- the wake-up sources[8] must be transparent to the µC

1.11. Diagnosis

The errors has to be recognised by the bus-driver and has to be signalled to the µC[9]:

- each bus-line error (e. g. short circuit to 5 V), which can be detected by a well-designed transceiver
- TX permanent dominant (the output-state has to be switched off)

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8 bus, wake-up, permanent power

9 the errors should be distinguished

- RX permanent recessive (the output-stage has to be switched off)
- RX short circuit to TX
- over temperature
- Bat-Fail (de-connection of the battery)
- wrong bus levels
- etc.

1.12. Pin-Out

- It is proposed to choose a pinning (package SO14) to allow the usage of high-speed bus drivers according the state or the art (package SO8).
- any short circuit between two neighbour pins may not block the communication
- the pins should be arranged looking to optimised pcb layouts

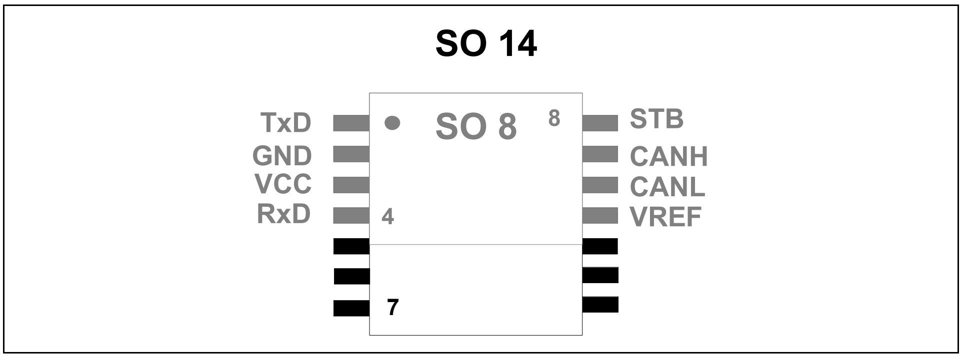

Figure 4

proposal for the pinning

Pin	Function	Remark
TxD	data stream to be sent	
GND	Ground	
VCC	5 V supply	
RxD	received data stream	
STB	control the operating mode	
CANH	bus line CAN high	fully protected - ESD, EMC, radiation, emission
CANL	bus line CAN low	fully protected - ESD, EMC, radiation, emission
VREF	average voltage at the bus	fully protected - ESD, EMC, radiation, emission
VBAT	permanent power	fully protected - ESD, EMC, radiation, emission
INH	control the voltage regulator	
ERR	recognised error	
EN	control the operating mode	
WU	wake-up	fully protected - ESD, EMC, radiation, emission
VCCµC	power of the µC	

Table 2 pins, their function and their protection

1.13. Fail Silence

The communication via the bus-lines may not be disturbed by any faulty ECU.

1.13.1. Tx permanent dominant

A permanent dominant Tx level may not disturb the communication via the bus lines.
→ recognise
→ handle (by de-activation of the output-stage after min. 200µs, recovery by the µC)
→ signal

1.13.2. Rx permanent recessive

A permanent recessive Rx level (if sending a message at Tx while the Rx-Pins stucks to recessive) may not disturb the communication via the bus lines.
→ recognise

→ handle (by de-activation of the output stage)
→ signal

1.13.3. Reverse Current

Not any reverse current is allowed independent from the operation mode incl. if being not powered.
→ Reverse (leakage) current on CAN-H and CAN-L (under the condition Vcc connected to GND) should be at most 50 µA at 2,5V (Target 0 µA).

Examples

- an ECU has a broken ground connection
  → the transceiver will float to the battery voltage
  → not any reverse current e. g. to the bus is allowed

- no reverse current from WU → VCC

2. Confirmed Behaviour

2.1. Wake-Up via the Bus

- the transceiver will be waked up by messages on the bus
  → predefined order of “0” and “1”
  → independent from the chosen baud-rate

- the bus lines are monitored by a differential mode comparator
  → common mode range ± (30 – 40 V)
  → any voltage outside the range common mode range ± (30 – 40 V) may not wake
  → amplitude de-modulator will be avoided

- each bus line has its own low pass filter regarding ground

2.2. Termination during the Power-Down Mode of the Bus

- each internal source will be passive
  → termination to ground
  → each wake-up will produce a common mode signal

2.3. States being transmitted to the µC

- battery failure (BatFail)
- temperature pre-warning
- bus-line failures
  → ... which support perfect communication
  → CAN_H to VCC or to the battery
  → CAN_L to Gnd
  → the recognised failure will be recovered so that the µC is able to recognise the failure by each interrupt an the end of a message
- Tx permanently dominant
- Rx permanently recessive
- Tx permanently short circuit to Rx - no

Distinction of the wake-up sources

- bus wake-up will be signalled by the pins ERR and RxD
- a WU wake-up will be signalled by the pin ERR

Transmission to the µC

- the states will be transmitted by the pin ERR to the µC

2.4. Pin-Out

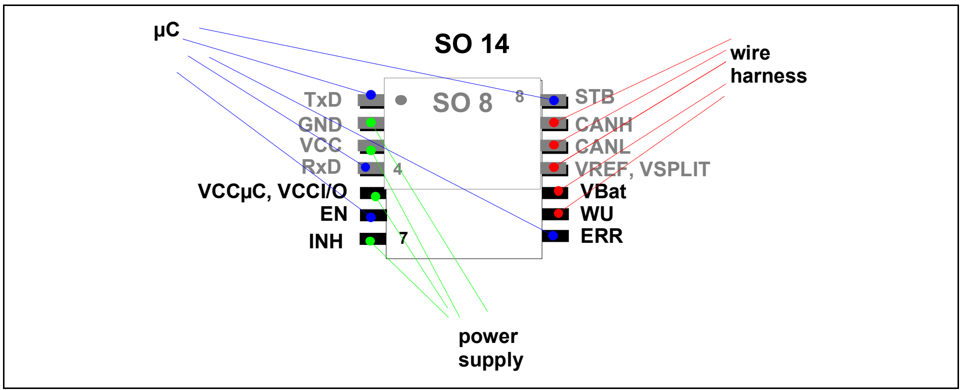

Figure 5

confirmed pin-out, based on a pin FMEA done by a chip supplier internally

2.5. Pins

2.5.1. Circuits

Wake-Up

- pull-up if the voltage at the WU is higher than the threshold
  pull-down if the voltage at WA is lower than the threshold
  or
  pull-up to UBat
- current limit (<10µA)
- external pull-up resistor recommended
- 2 level sensitivity
- threshold > 5 V (e.g. 6.5V[10]) if the static level is used
  threshold < 5 V, if edges are used
- interference comparable to the bus line wake-up circuit

RX

- standard CMOS output stage (without tri-state)

TX

- pull-up resistor, approx. 20kΩ

NERR

- low-side switch
- pull-up resistor to VCCµC (approx. 50kΩ)
- or a weak high-side switch

SB

- pull-down resistor
- approx. 20kΩ

EN

- pull-down resistor
- approx. 20kΩ

INH

- pull-up RDS to UBat
- approx. 3kΩ
- current limit (approx. 180µA)
- comparable to the low-speed implementation

2.5.2. Vref

- Behaviour TBD
  → source and sink (proposed)

[10] the threshold (> 5V) was chosen to handle a short circuit between WU and ERR

→ source
→ sink

3. Glossary

BattFail .... The bus-driver has been disconnected from the power lines.
Normal............................. The bus interface is in the running mode.
Standby .... The bus line outputs are terminated to support the power down mode of the network.
ECU .... Electronic Control Unit
Sleep .... Power down mode of the bus-driver - the external voltage regulator is not activated by the bus-driver.
TBD .... to be defined
uC..................................... Micro Controller

μC .... Micro Controller

5. Historie

Version	Date	Authors	Remarks
0.4		Jürgen Minuth (JM), Sven Fluhrer (SF), Andreas Gress (AG), Rainer Hägele (RH)	translation of version 0.3C into English
0.5	17.08.00	JM	integrated results from several meeting to be confirmed among the chip suppliers
0.6	4.10.00	JM	Updated pin-out and pin-behaviour introducing the 42 V requirement
0.7	20.02.02	SF	Update state transition chart
1.0	10.4.02	SF, JM, Dietmar Ostowski (DO), Oliver Richter (OR)	final review based on feedback from Audi, VW, Infineon, Motorola and Philips
1.1	17.07.02	OR, DO	integrated results from GIFT Meeting 28.05.02
1.1b	03.09.02	DO, SF	integrated results from GIFT Meeting 21.08.02
1.2	23.09.02	DO, OR	integrated feedback from GIFT Members