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**LIN SBC<sup>(1)</sup> including LIN Transceiver, Voltage Regulator,  
Window Watchdog and High-side Switch**

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**DATASHEET**

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**Features**

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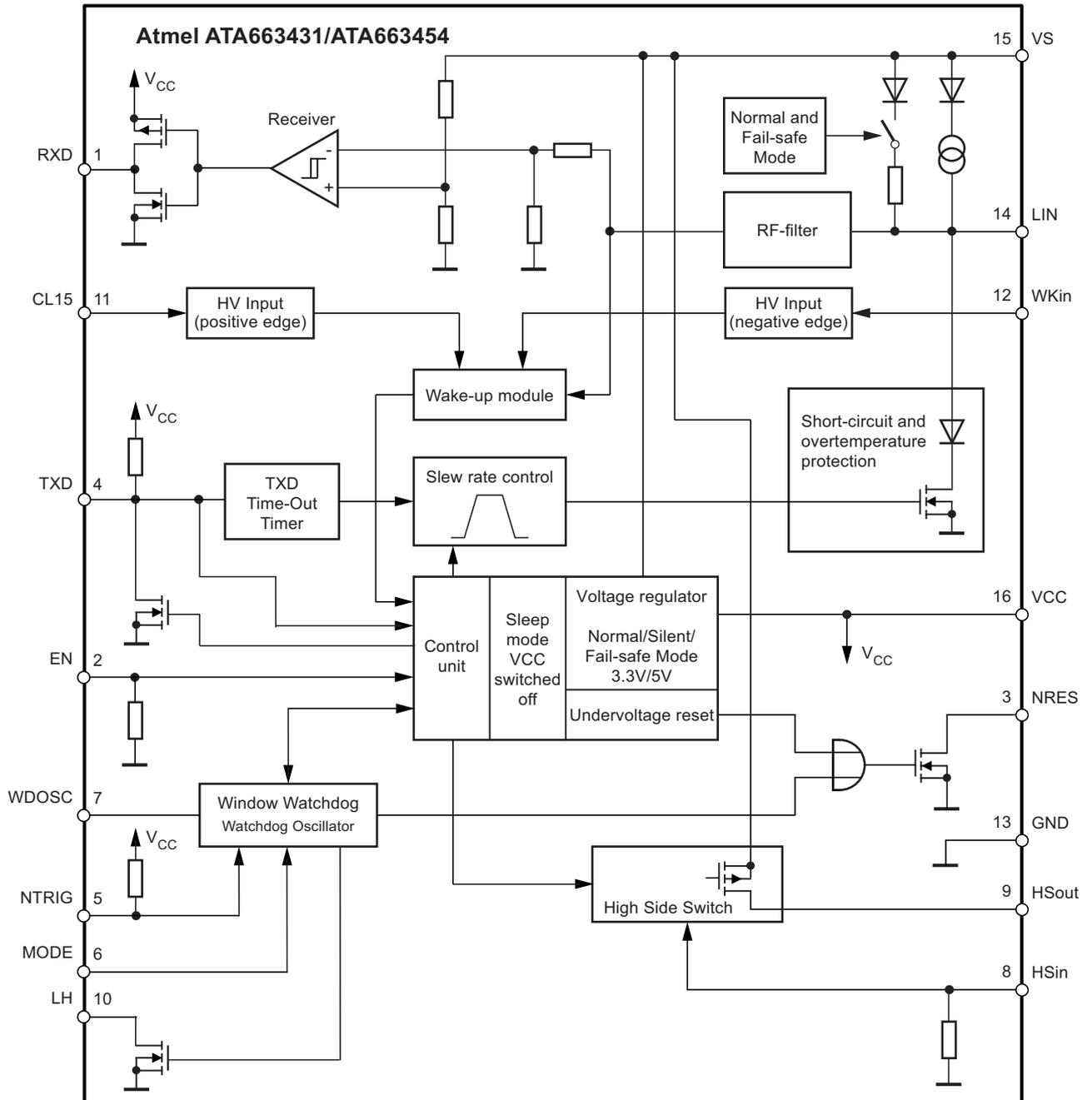
- Supply voltage up to 40V
- Operating voltage  $V_{VS} = 5V$  to 28V
- Supply current
  - Sleep mode: typically 10 $\mu$ A
  - Silent mode: typically 47 $\mu$ A
  - Very low current consumption at low supply voltages ( $2V < V_{VS} < 5.5V$ ): typically 150 $\mu$ A
- Linear low-drop voltage regulator, 85mA current capability:
  - MLC (multi-layer ceramic) capacitor with 0 $\Omega$  ESR
  - Normal, fail-safe, and silent mode
    - Atmel ATA663454:  $V_{CC} = 5.0V \pm 2\%$
    - Atmel ATA663431:  $V_{CC} = 3.3V \pm 2\%$
  - Sleep mode: VCC is switched off
- VCC undervoltage detection with open drain reset output (NRES, 4ms reset time)
- Voltage regulator is short-circuit and over-temperature protected
- Adjustable watchdog time via external resistor
- Negative trigger input for watchdog
- Limp Home watchdog failure output
- LIN physical layer according to LIN 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2
- Bus pin is overtemperature and short-circuit protected versus GND and battery
- High-side switch
- Wake-up capability via LIN Bus (100 $\mu$ s dominant), WKin pin and CL15 pin
- Wake-up source recognition
- TXD time-out timer
- Advanced EMC and ESD performance
- Fulfills the OEM "Hardware Requirements for LIN in Automotive Applications Rev.1.3"
- Interference and damage protection according to ISO7637
- Qualified according to AEC-Q100
- Package: DFN16 with wettable flanks (Moisture Sensitivity Level 1)

Note: 1. LIN SBC: LIN system basis chip

# 1. Description

Designed in compliance with LIN specifications 2.0, 2.1, 2.2, 2.2A and SAEJ2602-2, the Atmel® ATA663431/ATA663454 is a new generation of system basis chips with a fully integrated LIN transceiver, a low-drop voltage regulator (3.3V/5V/85mA), a window watchdog, and a high-side switch. This combination makes it possible to develop simple, but powerful, slave nodes in LIN-bus systems. Atmel ATA663431/ATA663454 is designed to handle low-speed data communication in vehicles (such as in convenience electronics). Improved slope control at the LIN driver ensures secure data communication up to 20Kbaud. The bus output is designed to withstand high voltage. Sleep mode and silent mode guarantee a minimized current consumption even in the case of a floating or short-circuited LIN bus.

Figure 1-1. Block Diagram



## 2. Pin Configuration

Figure 2-1. Pinning DFN16

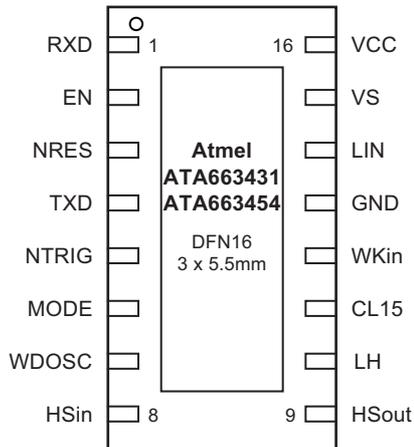


Table 2-1. Pin Description

Pin	Symbol	Function
1	RXD	Receive data output
2	EN	Enable normal mode if the input is high
3	NRES	VCC undervoltage output, open drain, low at reset
4	TXD	Transmit data input
5	NTRIG	Low-level watchdog trigger input from microcontroller; if not needed, connect to VCC
6	MODE	Control input for watchdog. Low: watchdog is on. High: watchdog is off
7	WDOSC	Connection for external resistor to set the watchdog frequency
8	HSin	High-side control input
9	HSout	High-side switch output
10	LH	Failure output of the watchdog (Limp Home), open drain
11	CL15	Ignition detection (edge sensitive); if not needed, connect to GND
12	WKin	High-voltage input for local wake-up request; if not needed, connect directly to VS
13	GND	Ground
14	LIN	LIN bus line input/output
15	VS	Supply voltage
16	VCC	Output voltage regulator 3.3V/5V/85mA
Backside		Heat slug, internally connected to GND

## 3. Pin Description

### 3.1 Supply Pin (VS)

LIN operating voltage is  $V_{VS} = 5V$  to  $28V$ . In order to avoid false bus messages, undervoltage detection is implemented to disable transmission if  $V_{VS}$  falls below  $V_{VS\_th\_N\_F\_down}$ . After switching on  $V_{VS}$ , the IC starts in fail-safe mode and the voltage regulator is switched on.

The supply current in sleep mode is typically  $10\mu A$  and  $47\mu A$  in silent mode.

### 3.2 Ground Pin (GND)

The IC does not affect the LIN bus in the event of GND disconnection. It can handle ground shifts of up to 11.5% with respect to  $V_{VS}$ .

### 3.3 Voltage Regulator Output Pin (VCC)

The internal 3.3V/5V voltage regulator is capable of driving loads up to 85mA, supplying the microcontroller and other ICs on the PCB, and is protected against overload by means of current limitation and overtemperature shutdown. Furthermore, the output voltage is monitored and causes a reset signal at the NRES output pin if it drops below a defined threshold

$V_{VCC\_th\_uv\_down}$ .

### 3.4 Undervoltage Reset Output Pin (NRES)

If the  $V_{VCC}$  voltage falls below the undervoltage detection threshold  $V_{VCC\_th\_uv\_down}$ , NRES switches to low after  $t_{res\_f}$ . Even if  $V_{VCC} = 0V$ , the NRES stays low because it is internally driven from the VS voltage. If VS voltage ramps down, NRES stays low until  $V_{VS} < 1.5V$  and then becomes high-impedant.

The undervoltage delay implemented keeps NRES low for  $t_{Reset} = 4ms$  after  $V_{VCC}$  reaches its nominal value.

### 3.5 Bus Pin (LIN)

A low-side driver is implemented with internal current limitation and thermal shutdown as well as an internal pull-up resistor in compliance with LIN specification 2.x. The voltage range is from  $-27V$  to  $+40V$ . This pin exhibits no reverse current from the LIN bus to VS, even in the event of a GND shift or supply disconnection. The LIN receiver thresholds comply with the LIN protocol specification.

The fall time (transition from recessive to dominant state) and the rise time (transition from dominant to recessive state) are slope-controlled.

During a short-circuit at the LIN pin to VBAT the output limits the output current to  $I_{BUS\_LIM}$ . Due to the power dissipation, the chip temperature exceeds  $T_{LINoff}$  and the LIN output is switched off. The chip cools down and, after a hysteresis of  $T_{hys}$ , switches the output on again. RXD stays on high because LIN is high. During LIN overtemperature switch-off, the VCC regulator works independently.

During a short circuit from LIN to GND the IC can be switched into sleep or silent mode and even in this case the current consumption is lower than  $100\mu A$  in sleep mode and lower than  $120\mu A$  in silent mode. If the short circuit disappears, the IC starts with a remote wake-up.

The reverse current is  $< 2\mu A$  at pin LIN during loss of  $V_{Bat}$ . This is optimal behavior for bus systems where some slave nodes are supplied from battery or ignition.

### 3.6 Bus Data Input/Output (TXD)

In normal mode the TXD pin is the microcontroller interface for controlling the state of the LIN output. TXD must be pulled to ground in order to drive the LIN bus low. If TXD is high or unconnected (internal pull-up resistor), the LIN output transistor is turned off and the bus is in the recessive state. If the TXD pin stays at GND level while switching into normal mode, it must be pulled to high longer than 10 $\mu$ s before the LIN driver can be activated. This feature prevents the bus line from being driven unintentionally to dominant state after normal mode has been activated (also in the case of a short circuit at TXD to GND). If TXD is short-circuited to GND, it is possible to switch to sleep mode via the EN pin after  $t > t_{dom}$ .

In fail-safe mode this pin is used as an output and signals the fail-safe source.

An internal timer prevents the bus line from being driven permanently in the dominant state. If TXD is forced to low longer than  $t_{dom} > 20$ ms, the LIN bus driver is switched to the recessive state. Nevertheless, when switching to sleep mode, the actual level at the TXD pin is relevant.

To reactivate the LIN bus driver, TXD needs to be set high for at least  $t_{DT0rel}$  (min 10 $\mu$ s).

### 3.7 Bus Data Output Pin (RXD)

In normal mode this pin reports the state of the LIN bus to the microcontroller. LIN high (recessive state) is indicated by a high level at RXD; LIN low (dominant state) is indicated by a low level at RXD. The output is a push-pull stage switching between VCC and GND. The AC characteristics are measured with an external load capacitor of 20pF.

In silent mode the RXD output switches to high.

### 3.8 Enable Input Pin (EN)

The enable input pin controls the operating mode of the device. If EN is high, the circuit is in normal mode, with the TXD to LIN and the LIN to RXD the transmission paths both active. The VCC voltage regulator operates with 3.3V/5V/85mA output capability.

If EN is switched to low while TXD is still high, the device is forced into silent mode. No data transmission is possible and the current consumption is reduced to  $I_{VSSilent}$  typ. 47 $\mu$ A. The VCC regulator maintains full functionality.

If EN is switched to low while TXD is low, the device is forced into sleep mode. This disables data transmission and the voltage regulator is switched off.

Pin EN provides a pull-down resistor to force the transceiver into recessive mode if EN is disconnected.

### 3.9 Wake Input Pin (WKin)

The WKin pin is a high-voltage input used for waking up the device from sleep mode or silent mode. It is usually connected to an external switch in the application to generate a local wake-up. A pull-up current source with typically 10 $\mu$ A is implemented. The voltage threshold for a wake-up signal is typically 2V below  $V_{VS}$ . If the WKin pin is not needed in the application, it can be connected directly to the VS pin.

### 3.10 CL15 Pin

The CL15 pin is a high-voltage input that can be used to wake up the device from sleep mode or silent mode. It is an edge-sensitive pin (low to-high transition). Thus, even if the CL15 pin is at high voltage ( $V_{CL15} > V_{CL15H}$ ), it is possible to switch the IC into sleep mode or silent mode. It is usually connected to the ignition for generating a local wake-up in the application if the ignition is switched on. The CL15 pin should be tied directly to ground if not needed. A debounce timer with a value  $t_{dbCL15}$  of typically 100 $\mu$ s is implemented. To protect this pin against transients, a serial resistor with 10k $\Omega$  and a ceramic capacitor with 47nF are recommended. With this RC combination you can increase the CL15 wake-up time.

### 3.11 WDOSC Output Pin

The WDOSC output pin provides a typical voltage of 1.23V intended to supply an external resistor with values between 34k $\Omega$  and 120k $\Omega$ . The value of the resistor adjusts the watchdog oscillator frequency to provide a certain range of time windows.

If the watchdog is disabled, the output voltage is switched off and the pin can either be tied to VCC or left open.

### 3.12 NTRIG Input Pin

The NTRIG input pin is the trigger input for the window watchdog. A pull-up resistor is implemented. A falling edge triggers the watchdog. The trigger signal (low) must exceed a minimum time of  $t_{\text{trigmin}}$  to generate a watchdog trigger and avoid false triggers caused by transients.

### 3.13 Mode Input Pin (MODE)

Connect the MODE pin directly or via an external resistor to GND for normal watchdog operation. To debug the software of the connected microcontroller, connect the MODE pin to VCC and the watchdog is switched off. For fail-safe reasons, the MODE pin has a self-holding function, pulling the input to ground (i.e., watchdog enabled) in case of an open connection.

Note: If you do not use the watchdog, connect the mode pin directly to VCC.

### 3.14 Limp Home Watchdog Failure Output (LH)

The LH output pin indicates a failure of the watchdog. It is realized as a high-voltage open drain NMOS structure. During power up or after a wake-up from sleep mode the LH output is switched off. As the watchdog is only working in normal and fail-safe mode, the state of the LH output transistor can change only in these two modes. In silent mode the LH output remains in the same state as it was before switching into silent mode.

If a watchdog reset occurs, the LH output transistor switches on immediately, and it switches off only after three correct consecutive watchdog trigger pulses have been occurred at the NTRIG pin.

### 3.15 High-side Switch Pins (HSout, HSin)

This high-side switch is designed for low-power loads such as LEDs, sensors or a voltage divider for measuring the supply voltage. It is functional in all operating modes of the chip except for sleep mode. Its structure is connected to the VS supply pin. This pin is short-circuit protected and also protected against overheating, whereas the protective shutdown is debounced and latched. In other words, after a protective shutdown of the output switch, the control line HSin has to go to low level first before the output can be restarted again.

The high-side switch is controlled via the low-voltage input pin HSin. If the input is high, the output is switched on. For fail-safe reasons, the HSin input is equipped with a pull-down resistor to GND. This keeps the high-side switch off in case of a missing connection from the controller.

Please note that in case of a disconnected system ground, the module can be supplied via the connected load on the high-side output and an internal ESD structure. This is the case if the load has a different ground connection than the PCB. See also the “Absolute Maximum Ratings” section for current limits in such cases.

## 4. Functional Description

### 4.1 Physical Layer Compatibility

Because the LIN physical layer is independent of higher LIN layers (such as the LIN protocol layer), all nodes with a LIN physical layer according to revision 2.x can be mixed with LIN physical layer nodes found in older versions (i.e., LIN 1.0, LIN 1.1, LIN 1.2, LIN 1.3) without any restrictions.

### 4.2 Operating Modes

Figure 4-1. Operating Modes

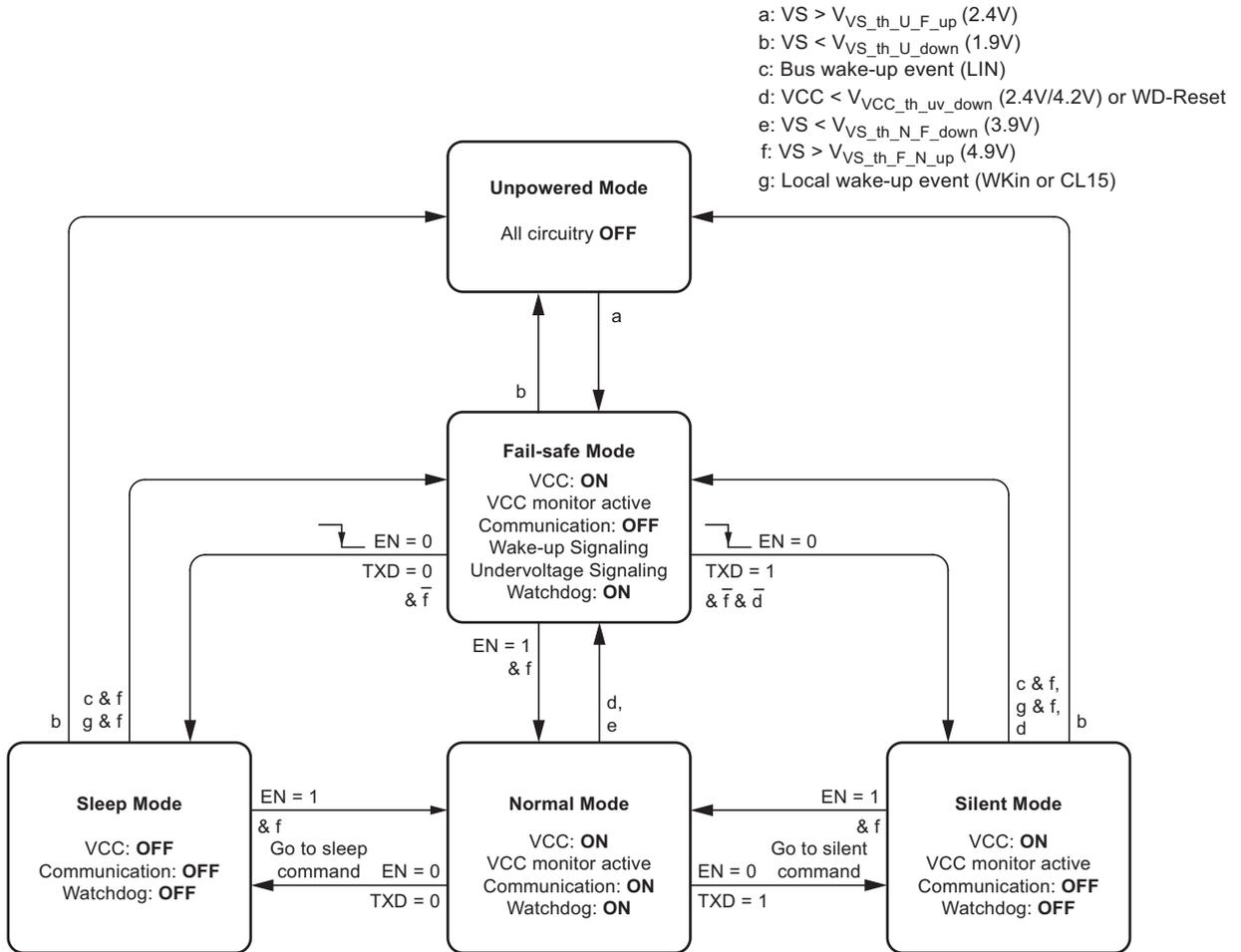


Table 4-1. Operating Modes (Mode Pin Is Always Low)

Operating Modes	Transceiver	Voltage Regulator	Watchdog	LH	High-Side Output	LIN	TXD	RXD
Fail-safe	OFF	ON	ON	WD dependent	HSin-dependent	Recessive	Signaling fail-safe sources (see Table 4-2)	
Normal	ON	ON	ON	WD dependent	HSin-dependent	TXD dependent	Follows data transmission	
Silent	OFF	ON	OFF	Remains in previous state	HSin-dependent	Recessive	High	High
Sleep/Unpowered	OFF	OFF	OFF	OFF	OFF	Recessive	Low	Low

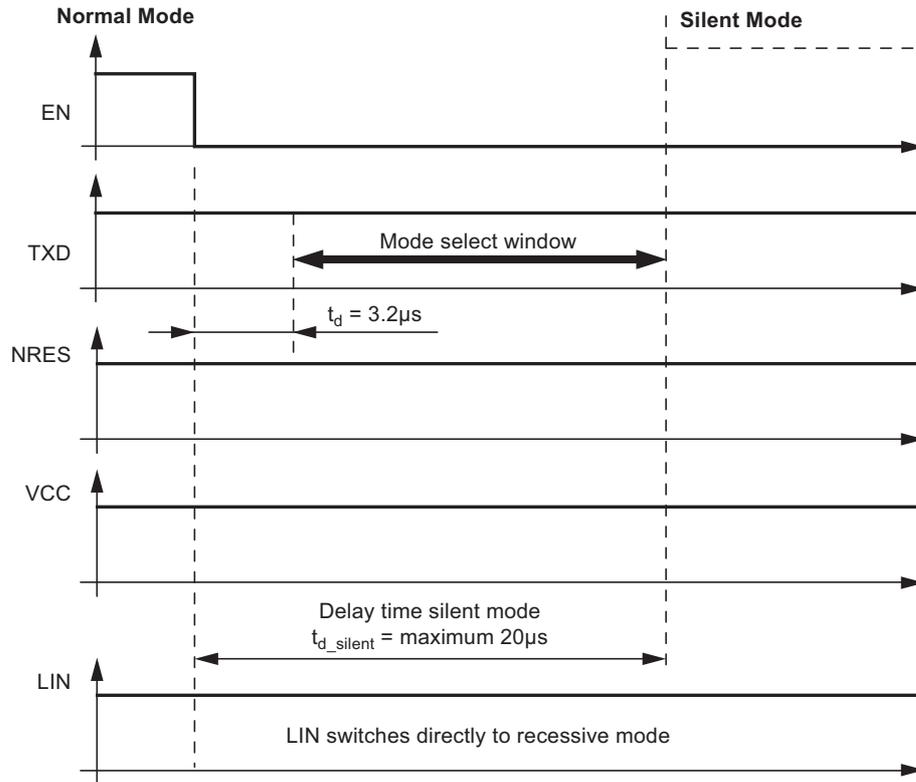
### 4.2.1 Normal Mode

This is the normal transmission and receiving mode of the LIN interface. The VCC voltage regulator works with 3.3V/5V output voltage. The watchdog needs a trigger signal from NTRIG to avoid resets at NRES. If NRES switches to low, the IC changes its state to fail-safe mode.

### 4.2.2 Silent Mode

A falling edge at EN while TXD is high switches the IC into silent mode. The TXD signal has to be logic high during the mode select window. The transmission path is disabled in silent mode. The voltage regulator is active. The overall supply current from VBAT is a combination of the  $I_{VSSilent}$  of typ. 47 $\mu$ A plus the VCC regulator output current  $I_{VCC}$ .

Figure 4-2. Switching to Silent Mode



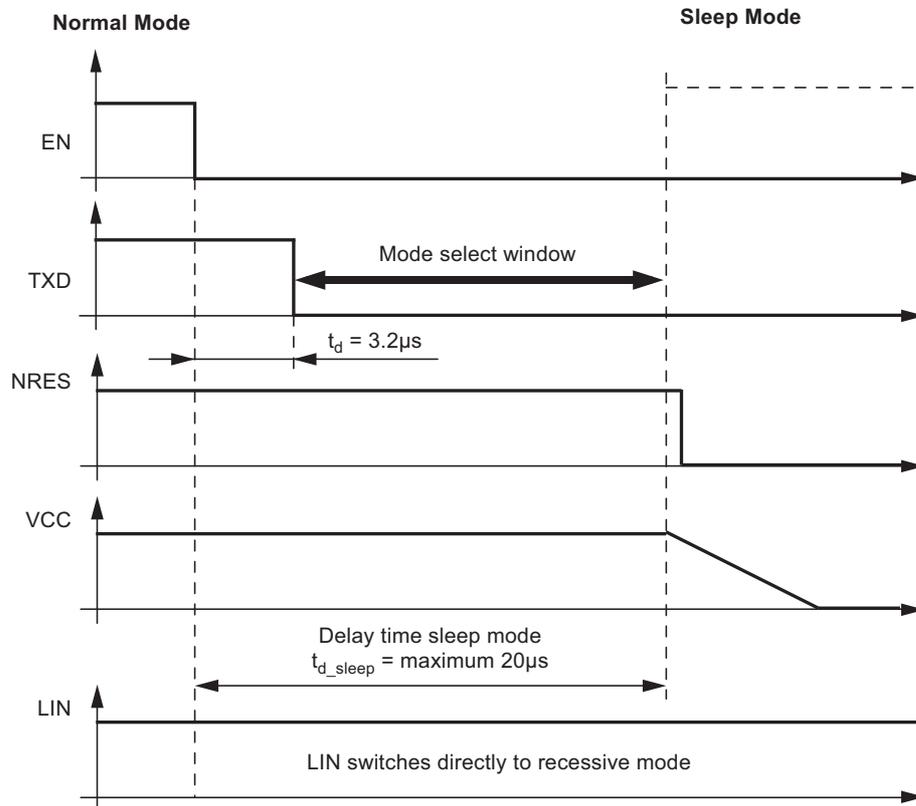
In silent mode, the internal slave termination between the LIN pin and VS pin is disabled to minimize current consumption in case the LIN pin is short-circuited to GND. Only a weak pull-up current (typically 10 $\mu$ A) is present between the LIN pin and the VS pin. Silent mode can be activated regardless of the current level on the LIN pin or WKin pin.

If an undervoltage condition occurs, NRES is switched to low and the Atmel ATA663431/ATA663454 changes its state to fail-safe mode.

### 4.2.3 Sleep Mode

A falling edge at EN while TXD is low switches the IC to sleep mode. The TXD signal has to be logic low during the mode select window.

Figure 4-3. Switching to Sleep Mode



In order to avoid any influence on the LIN pin while switching into sleep mode, it is possible to switch the EN to low up to 3.2µs earlier than the TXD. The best and easiest way is to generate two simultaneous falling edges at TXD and EN.

The transmission path is disabled in sleep mode. Supply current from VBAT is typically  $I_{V_{S\text{sleep}}} = 10\mu\text{A}$ . The VCC regulator is switched off; NRES and RXD are low. The internal slave termination between the LIN and VS pins is disabled to minimize current consumption in case the LIN pin is short-circuited to GND. Only a weak pull-up current (typically 10µA) between the LIN pin and VS pin is present. Sleep mode can be activated independently from the current level on the LIN pin. A voltage less than the LIN pre-wake detection  $V_{\text{LINL}}$  at the LIN pin activates the internal LIN receiver and starts the wake-up detection timer.

If TXD is short-circuited to GND, it is possible to switch to sleep mode via EN after  $t > t_{\text{dom}}$ .

#### 4.2.4 Fail-Safe Mode

The device automatically switches to fail-safe mode at system power-up. The voltage regulator and the watchdog are switched on. The NRES output remains low for  $t_{res} = 4\text{ms}$  and resets the microcontroller. LIN communication is switched off. The IC stays in this mode until EN is switched to high. The IC then changes to normal mode. A low at NRES switches the IC directly into fail-safe mode. During fail-safe mode the TXD pin is an output and together with the RXD output pin transmits a signal indicating the fail-safe source.

If the device enters fail-safe mode coming from normal mode ( $EN=1$ ) due to a  $V_{VS}$  undervoltage condition ( $V_{VS} < V_{VS\_th\_N\_F\_down}$ ), it is possible to switch to sleep mode or silent mode through a falling edge at the EN input. The current consumption can be reduced further with this feature.

A wake-up event from either silent mode or sleep mode is indicated to the microcontroller using the two pins RXD and TXD. A  $V_{VS}$  undervoltage condition is also indicated at these two pins. The coding is shown in [Table 4-2](#).

A wake-up event switches the IC to fail-safe mode.

**Table 4-2. Signaling in Fail-safe Mode**

Fail-Safe Sources	TXD	RXD
LIN wake-up (LIN pin)	Low	Low
Local wake-up (WKIn pin or CL15 pin)	Low	High
$V_{VS\_th\_N\_F\_down}$ (battery) undervoltage detection ( $V_{VS} < 3.9\text{V}$ )	High	Low

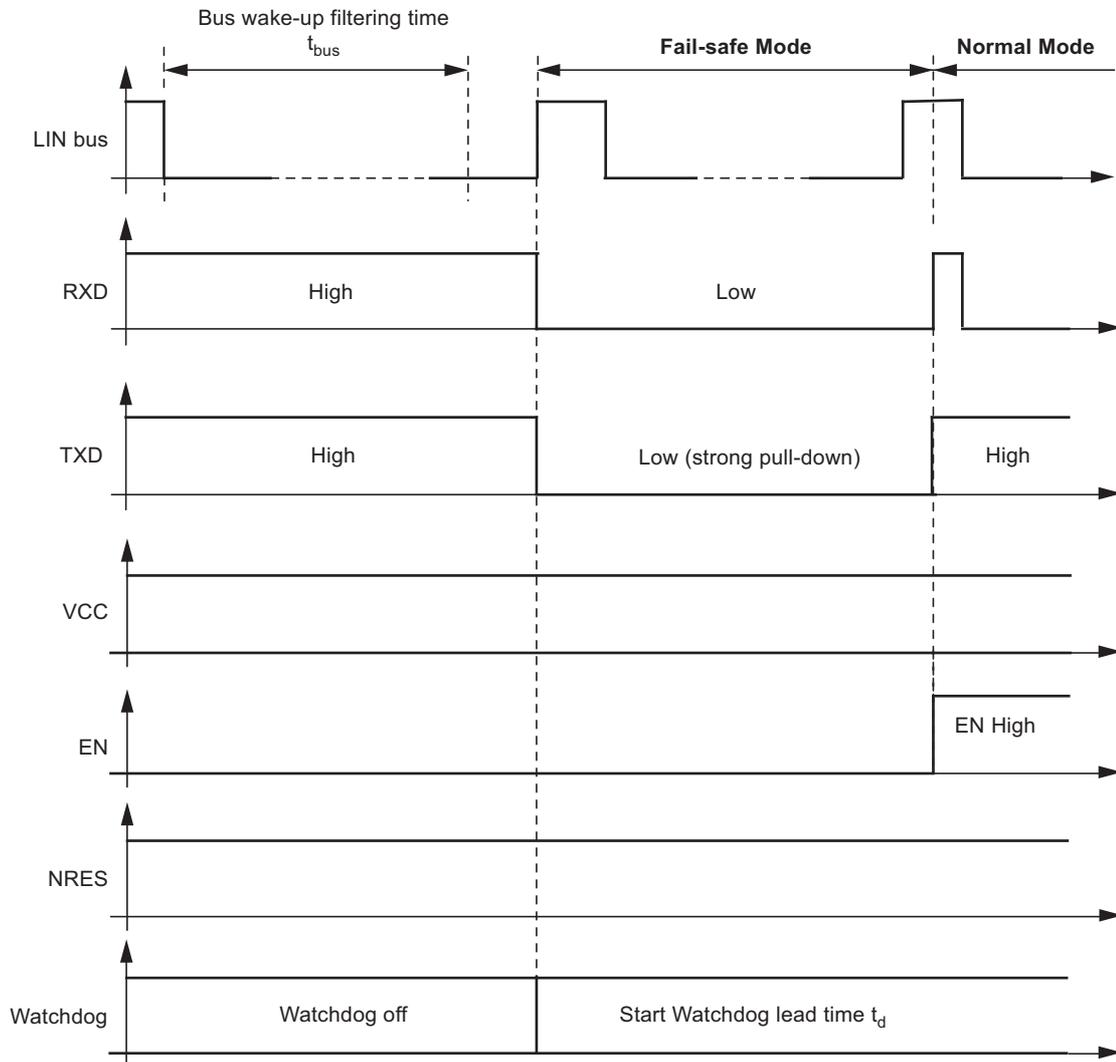
## 4.3 Wake-up Scenarios from Silent Mode or Sleep Mode

### 4.3.1 Remote Wake-up via LIN Bus

#### 4.3.1.1 Remote Wake-up from Silent Mode

A remote wake-up from silent mode is only possible if TXD is high. A voltage less than the LIN pre-wake detection  $V_{LINL}$  at the LIN pin activates the internal LIN receiver and starts the wake-up detection timer. A falling edge at the LIN pin followed by a dominant bus level maintained for a given time period ( $> t_{bus}$ ) and the following rising edge at the LIN pin (see [Figure 4-4](#)) result in a remote wake-up request. The device switches from silent mode to fail-safe mode, the VCC voltage regulator remains activated and the internal LIN slave termination resistor is switched on. The remote wake-up request is indicated by a low level at the RXD and TXD pins (strong pull-down at TXD). EN high can be used to switch directly to normal mode.

**Figure 4-4. LIN Wake-up from Silent Mode**



### 4.3.1.2 Remote Wake-up from Sleep Mode

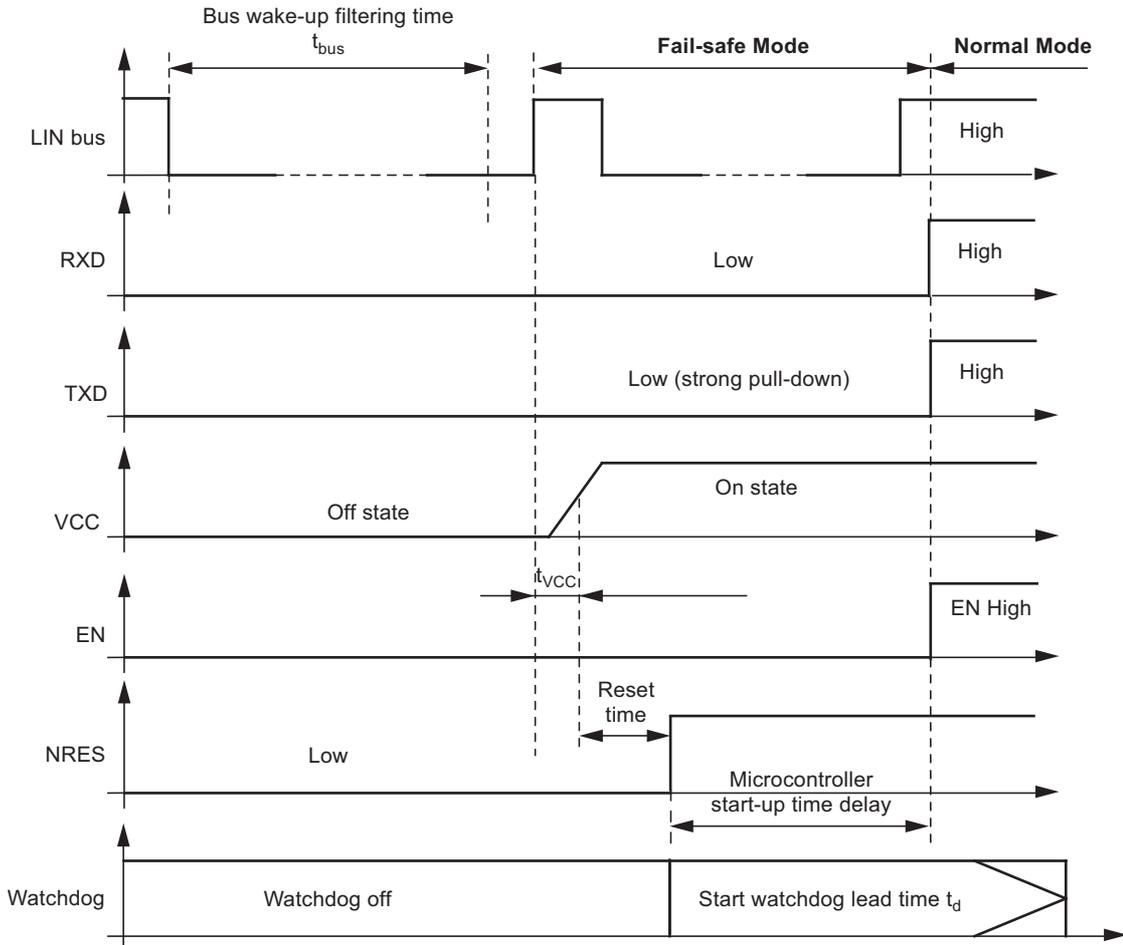
A voltage less than the LIN pre-wake detection  $V_{LINL}$  at the LIN pin activates the internal LIN receiver and starts the wake-up detection timer.

A falling edge at the LIN pin followed by a dominant bus level maintained for a given time period ( $> t_{bus}$ ) and a subsequent rising edge at the LIN pin results in a remote wake-up request. The device switches from sleep mode to fail-safe mode.

The VCC regulator is activated, and the internal LIN slave termination resistor is switched on. The remote wake-up request is indicated by a low level at RXD and TXD (strong pull-down at TXD).

EN high can be used to switch directly from sleep/silent to fail-safe mode. If EN is still high after  $V_{CC}$  ramp-up and the undervoltage reset time, the IC switches to normal mode.

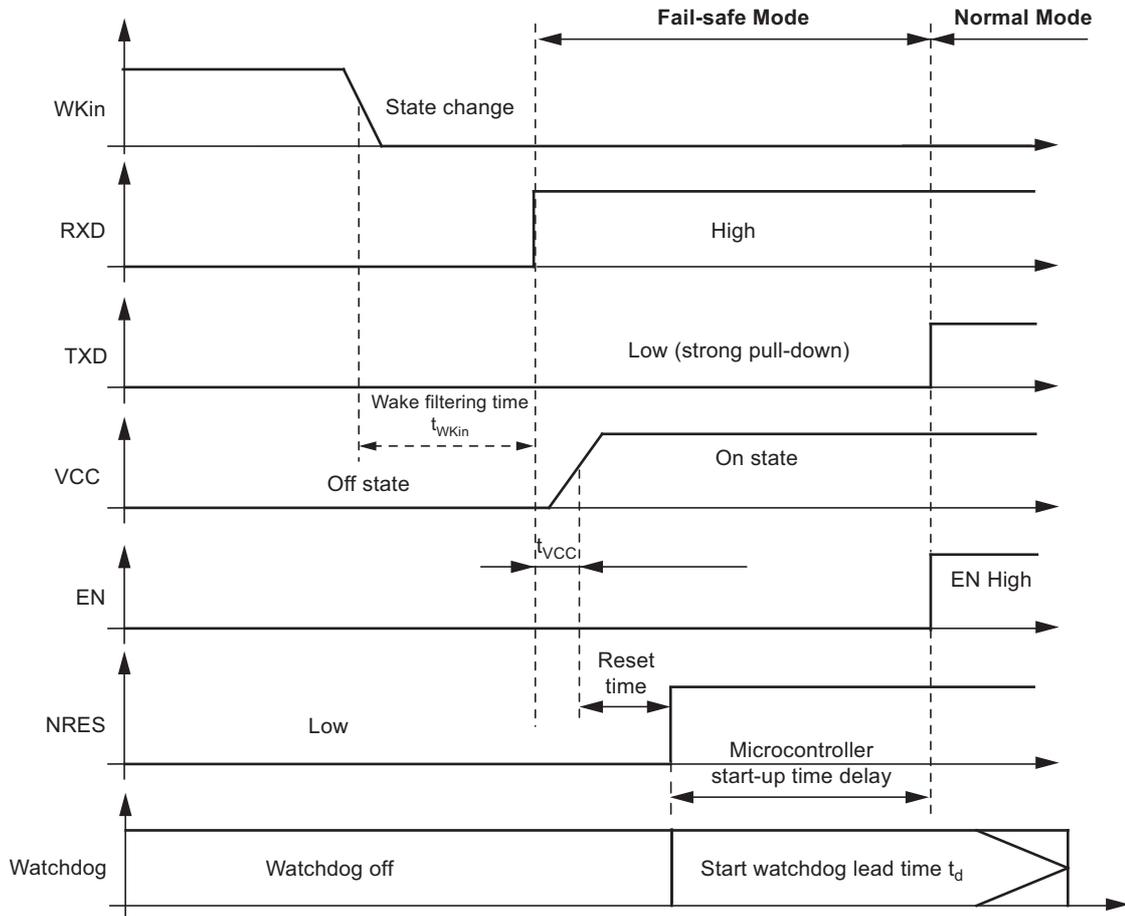
**Figure 4-5. LIN Wake-up from Sleep Mode**



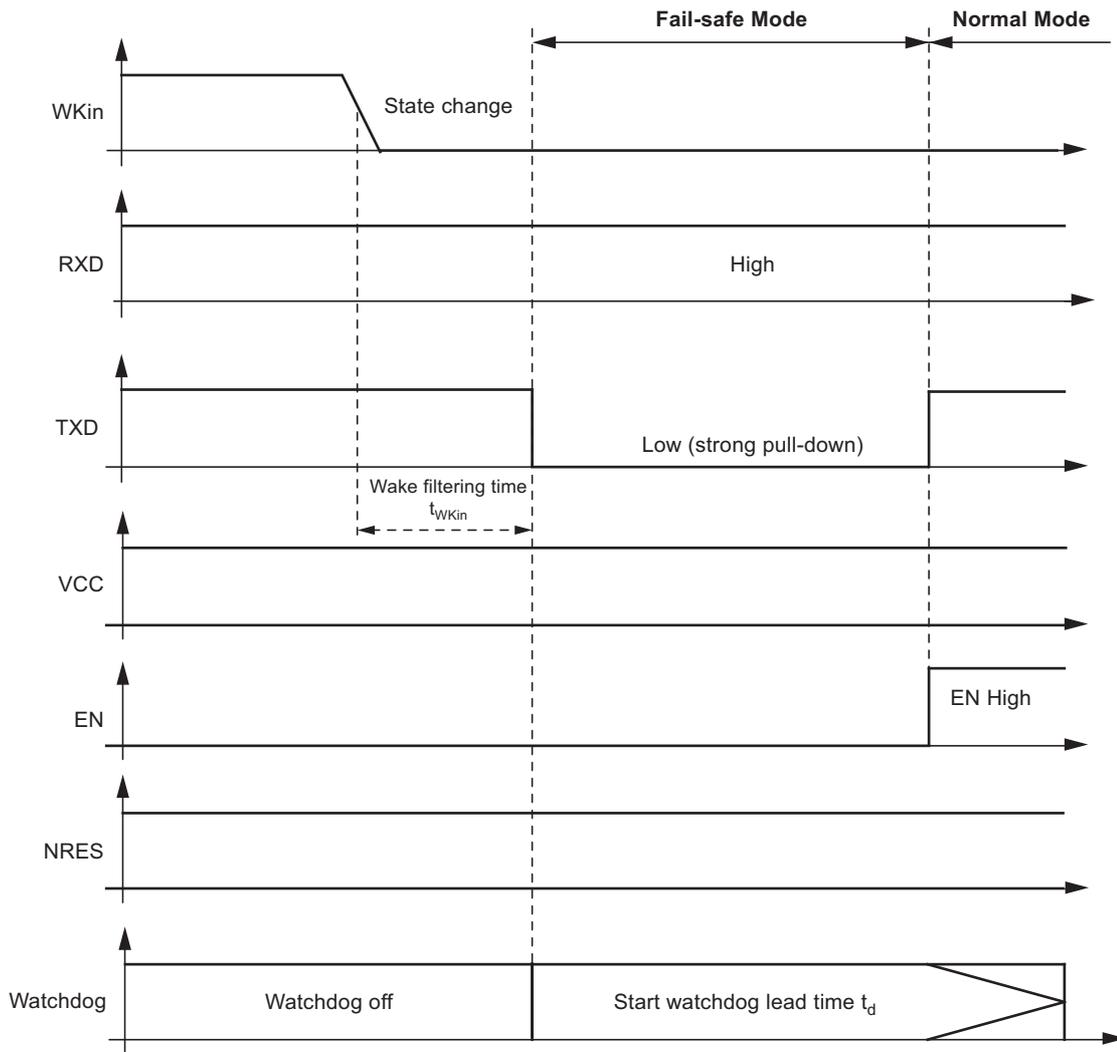
### 4.3.2 Local Wake-up via WKin Pin

A falling edge at the WKin pin followed by a low level maintained for a given time period ( $> t_{WKin}$ ) results in a local wake-up request. The device switches to fail-safe mode. The internal slave termination resistor is switched on. The local wake-up request is indicated by a low level at the TXD pin to generate an interrupt for the microcontroller. When the WKin pin is low, it is possible to switch to silent mode or sleep mode via the EN pin. In this case, the wake-up signal has to be switched to high  $> 10\mu s$  before the negative edge at WKin starts a new local wake-up request.

Figure 4-6. Local Wake-up via WKin pin from Sleep Mode



**Figure 4-7. Local Wake-up via WKin pin from Silent Mode**



### 4.3.3 Local Wake-up via CL15

A voltage on pin CL15 above  $V_{CL15H}$  for at least  $t_{dbCL15}$  results in a local wake-up request. The device switches to fail-safe mode. The internal slave termination resistor is switched on. The local wake-up request is indicated by a low level at the TXD pin to generate an interrupt for the microcontroller. Even when the CL15 pin is high, it is possible to switch to silent mode or sleep mode via the EN pin. In this case, the wake-up signal at CL15 has to be switched to low  $> 10\mu s$  before the rising edge at CL15 starts a new local wake-up request.

### 4.3.4 Wake-up Source Recognition

The device can distinguish between different wake-up sources (see Table 4-3). The wake-up source can be read on the TXD and RXD pin in fail-safe mode. These flags are immediately reset if the microcontroller sets the EN pin to high and the IC is in normal mode.

**Table 4-3. Signaling in Fail-safe Mode**

Fail-Safe Sources	TXD	RXD
LIN wake-up (LIN pin)	Low	Low
Local wake-up (WKin pin or CL15 pin)	Low	High
$V_{VS\_th\_N\_F\_down}$ (battery) undervoltage detection ( $V_{VS} < 3.9V$ )	High	Low

## 4.4 Behavior under Low Supply Voltage Conditions

After the battery voltage has been connected to the application circuit, the voltage at the VS pin increases according to the block capacitor (see Figure 4-12 on page 17). If  $V_{VS}$  is higher than the minimum  $V_{VS}$  operation threshold  $V_{VS\_th\_U\_F\_up}$  (typ. 2.25V), the IC mode changes from unpowered mode to fail-safe mode. As soon as  $V_{VS}$  exceeds the undervoltage threshold  $V_{VS\_th\_F\_N\_up}$  (typ. 4.6V), the LIN transceiver can be activated. The VCC output voltage reaches its nominal value after  $t_{VCC}$ . This parameter depends on the externally applied VCC capacitor and the load. The NRES output is low for the reset time delay  $t_{reset}$ . No mode change is possible during this time  $t_{reset}$ .

The behavior of VCC, NRES and VS is shown in following diagrams (ramp-up and ramp-down):

Figure 4-8. VCC and NRES versus VS (Ramp-up) for ATA663431

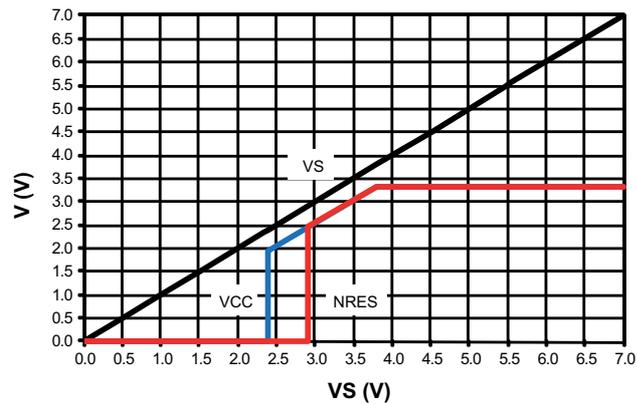


Figure 4-9. VCC and NRES versus VS (Ramp-down) for ATA663431

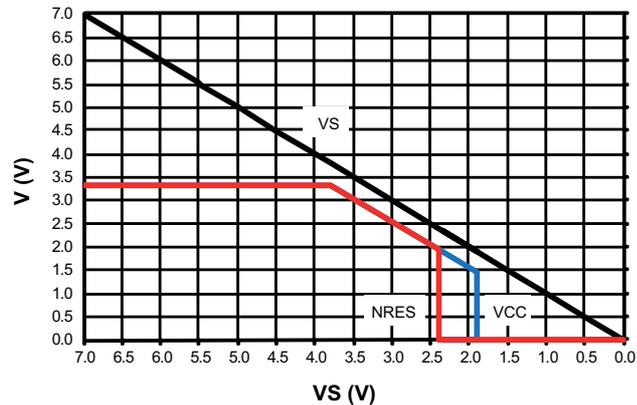


Figure 4-10. VCC and NRES versus VS (Ramp-up) for ATA663454

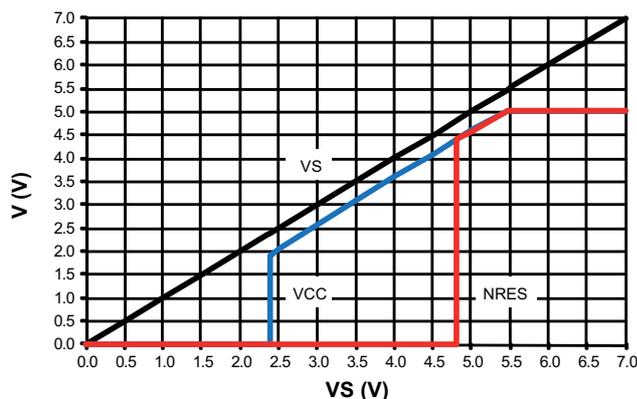
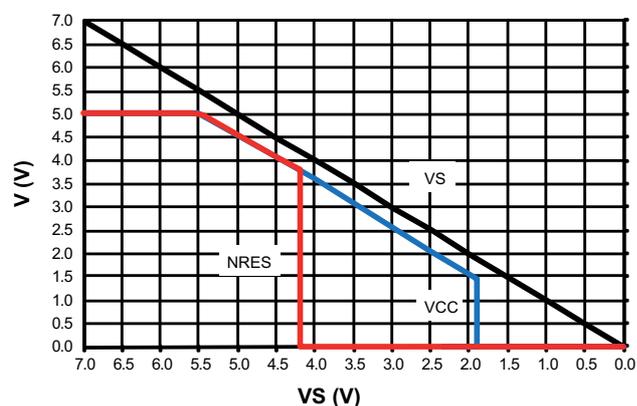


Figure 4-11. VCC and NRES versus VS (Ramp-down) for ATA663454



Please note that the upper graphs are only valid if the  $V_{VS}$  ramp-up and ramp-down time is much slower than the VCC ramp-up time  $t_{VCC}$  and the NRES delay time  $t_{reset}$ .

If during **sleep mode** the voltage level of  $V_{VS}$  drops below the undervoltage detection threshold  $V_{VS\_th\_N\_F\_down}$  (typ. 4.3V), the operating mode is not changed and no wake-up is possible. Only if the supply voltage on pin VS drops below the  $V_{VS}$  operation threshold  $V_{VS\_th\_U\_down}$  (typ. 2.05V) does the IC switch to unpowered mode.

If during **silent mode** the VCC voltage drops below the VCC undervoltage threshold  $V_{VCC\_th\_uv\_down}$  the IC switches into fail-safe mode. If the supply voltage on pin VS drops below the  $V_{VS}$  operation threshold  $V_{VS\_th\_U\_down}$  (typ. 2.05V), does the IC switch to unpowered mode.

If during **normal mode** the voltage level on pin VS drops below the  $V_{VS}$  undervoltage detection threshold  $V_{VS\_th\_N\_F\_down}$  (typ. 4.3V), the IC switches to fail-safe mode. This means the LIN transceiver is disabled in order to avoid malfunctions or false bus messages. The voltage regulator remains active.

**For ATA663431:** In this undervoltage situation, it is possible to switch the device into sleep mode or silent mode through a falling edge at the EN input pin. This feature ensures that it is always possible to switch to these two current saving modes so that current consumption can be reduced even further.

When the VCC voltage drops below the VCC undervoltage threshold  $V_{VCC\_th\_uv\_down}$  (typ. 2.6V) the IC switches into fail-safe mode.

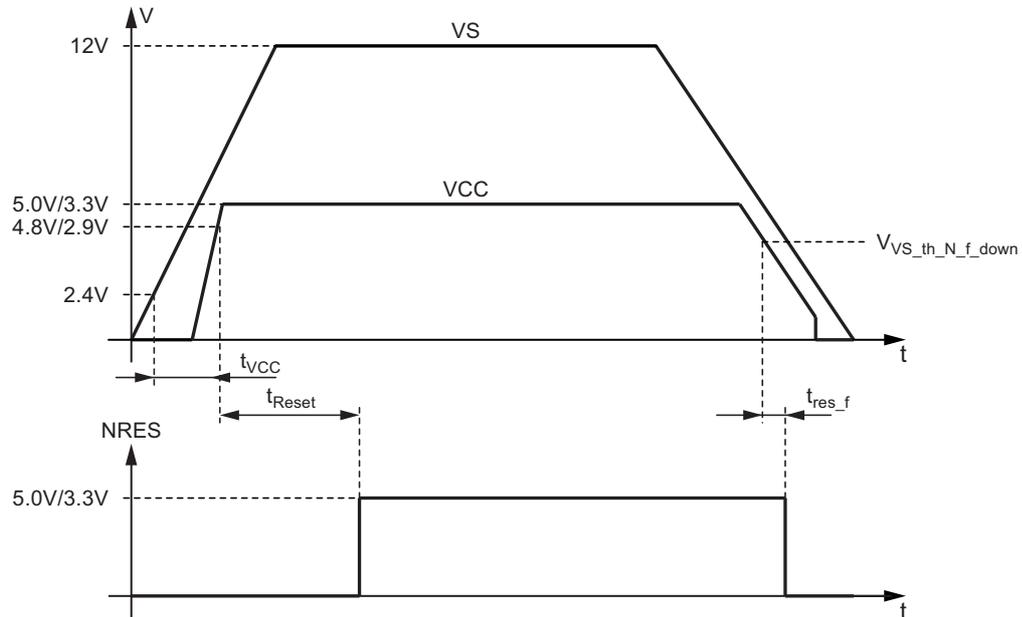
**For ATA663454:** Because of the VCC undervoltage condition in this situation, the IC is in fail-safe mode and can be switched into sleep mode only.

Only when the supply voltage  $V_{VS}$  drops below the operation threshold  $V_{VS\_th\_U\_down}$  (typ. 2.05V) does the IC switch into unpowered mode.

The current consumption of the ATA663431/ATA663454 in silent mode is always below 200 $\mu$ A, even when the supply voltage  $V_{VS}$  is lower than the regulator's nominal output voltage VCC.

## 4.5 Voltage Regulator

Figure 4-12. VCC Voltage Regulator: Supply Voltage Ramp-up and Ramp-down

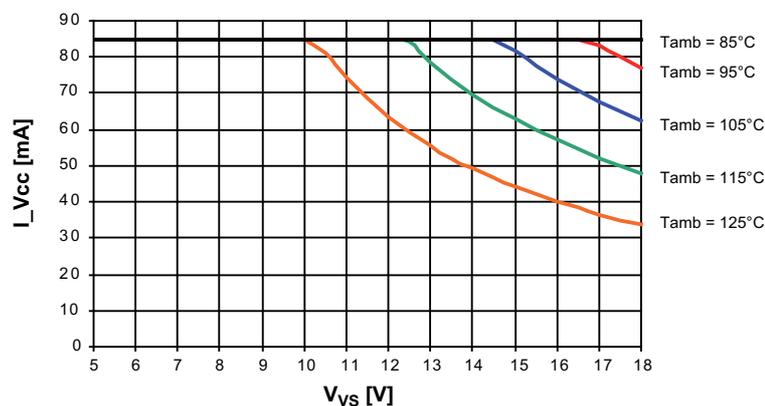


The voltage regulator needs an external capacitor for compensation and to smooth the disturbances from the microcontroller. It is recommended to use a MLC capacitor with a minimum capacitance of 1.8 $\mu$ F together with a 100nF ceramic capacitor. Depending on the application, the values of these capacitors can be modified by the customer.

When the Atmel ATA663431/ATA663454 is being soldered onto the PCB, it is mandatory to connect the heat slug with a wide GND plate on the printed board to achieve a good heat sink.

The main power dissipation of the IC is created from the VCC regulator output current  $I_{VCC}$ , which is needed for the application. Figure 4-13 shows the safe operating area of the Atmel ATA663431/ATA663454 without considering any output current of the high-side output HSOUT.

Figure 4-13. Power Dissipation: Safe Operating Area: Regulator's Output Current  $I_{VCC}$  versus Supply Voltage  $V_{VS}$  at Different Ambient Temperatures ( $R_{thja} = 45K/W$  assumed)



## 4.6 Watchdog

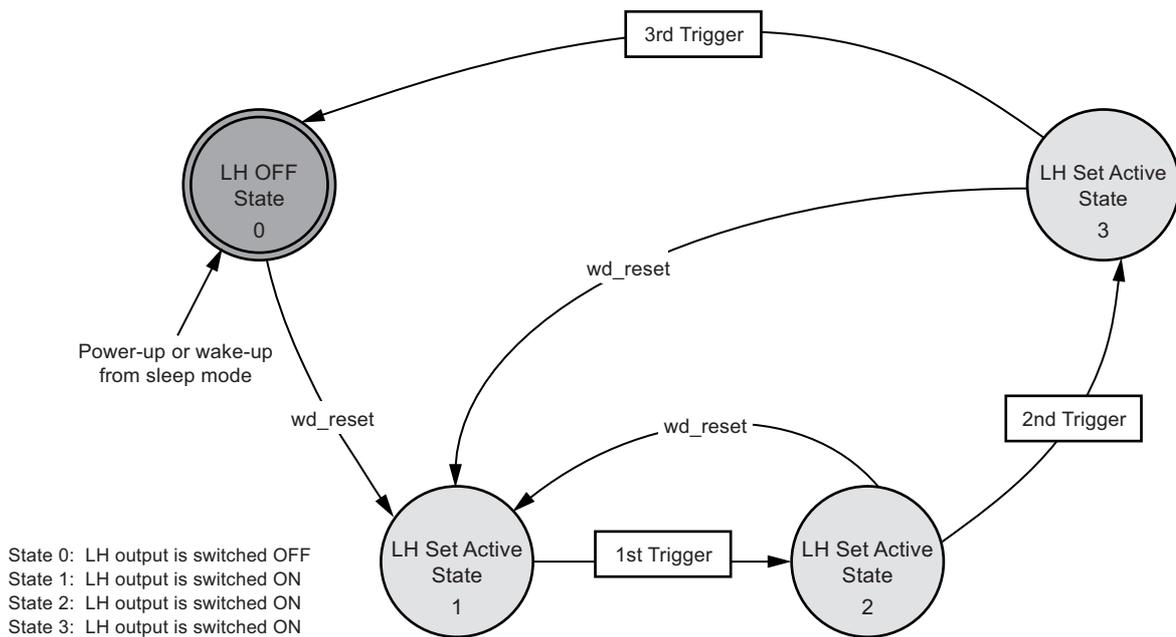
The watchdog anticipates a trigger signal from the microcontroller at the NTRIG (negative edge) input within a time window of  $t_{wd}$ . The trigger signal must exceed a minimum time of  $t_{trigmin} > 200ns$ . If a trigger signal is not received, a reset signal is generated at output NRES and the LH output transistor switches on. The timing basis of the watchdog is provided by the internal oscillator. Its time period,  $t_{osc}$ , is adjustable via the external resistor  $R_{WDOSC}$  (34k $\Omega$  to 120k $\Omega$ ). During silent or sleep mode the watchdog is switched off to reduce current consumption. The minimum time for the first watchdog pulse is required after the undervoltage reset at NRES disappears, it is defined as lead time  $t_d$ . After wake-up from sleep mode, the lead time  $t_d$  starts with the rising edge at the NRES output. After a wake-up from silent mode, the lead time  $t_d$  starts with the falling edge at the TXD pin.

The Limp Home output LH is a high voltage NMOS open drain structure which is signaling watchdog failures. It works independently of the VCC voltage. So it is possible to switch on some external devices in the case of a watchdog failure independent from the microcontroller and the VCC voltage. During power up or after a wake-up from sleep mode the LH output is switched off. If a watchdog reset occurs, the LH output transistor switches on immediately, and it switches off only after three correct consecutive watchdog trigger pulses have been occurred at the NTRIG pin.

As the watchdog is only working in normal and fail-safe mode, the state of the LH output transistor can change only in these two modes. In silent mode the LH output remains in the same state as it was before switching into silent mode. When the watchdog is disabled via a high level at the mode pin or during sleep or unpowered mode, the LH output is also disabled.

The behavior of the LH output when the watchdog is active during fail-safe and normal mode is depicted in Figure 4-14.

**Figure 4-14. Limp Home (LH) State Diagram**



In sleep mode and unpowered mode the watchdog and therefore the LH output are deactivated. In silent mode the LH output remains in the same state as it was before switching into silent mode

#### 4.6.1 Typical Timing Sequence with $R_{WDOSC} = 51k\Omega$

The trigger signal  $t_{wd}$  is adjustable between 20ms and 64ms using the external resistor  $R_{WDOSC}$ .

For example, with an external resistor of  $R_{WDOSC} = 51k\Omega \pm 1\%$ , the typical parameters of the watchdog are as follows:

$$t_{osc} = (0.405 \times R_{WDOSC} - 0.0004 \times (R_{WDOSC})^2) \times 2 \quad (R_{WDOSC} \text{ in } k\Omega ; t_{osc} \text{ in } \mu s)$$

$$t_{osc} = 39.3\mu s \text{ due to } 51k\Omega$$

$$t_d = 3984 \times 39.2\mu s = 154.8ms$$

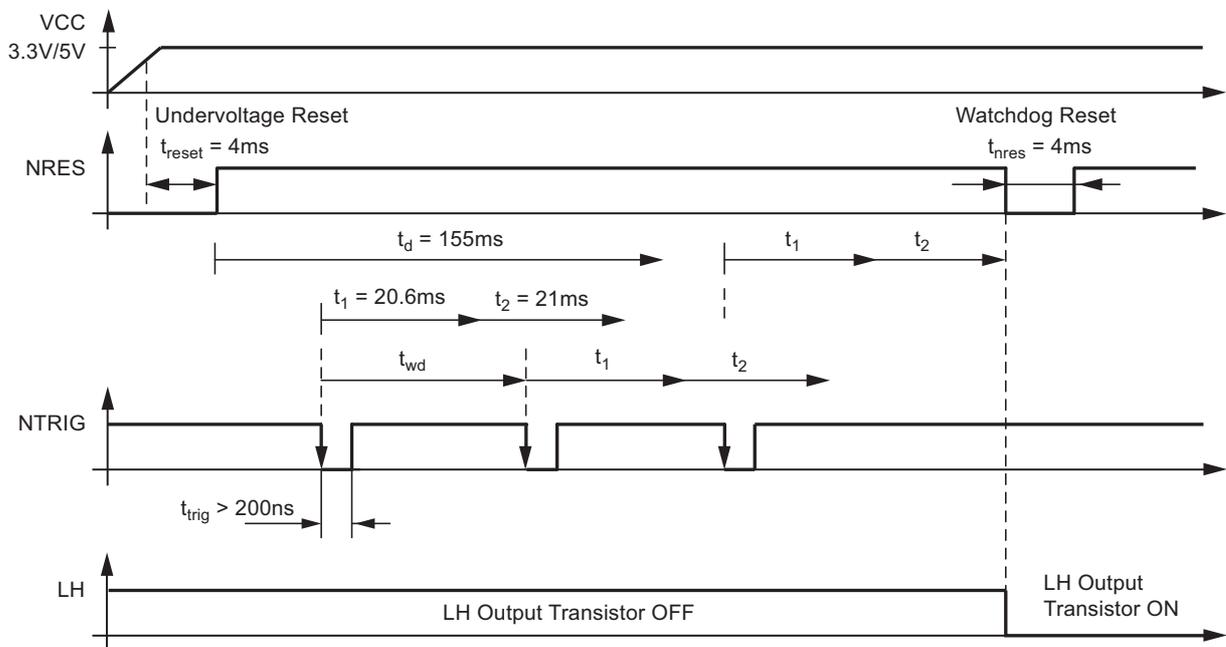
$$t_1 = 527 \times 39.2\mu s = 20.6ms$$

$$t_2 = 553 \times 39.3\mu s = 21.6ms$$

$$t_{nres} = \text{constant} = 4ms$$

After ramping up the battery voltage, the 5V regulator is switched on. The reset output NRES stays low for the time  $t_{reset}$  (typically 4ms), then it switches to high and the watchdog waits for the trigger sequence from the microcontroller. During power up or after a wake-up from sleep mode the LH output is switched off. If a watchdog reset occurs, the LH output transistor switches on immediately, and it switches off only after three correct consecutive watchdog trigger pulses have been occurred at the NTRIG pin. The lead time,  $t_d$ , follows the reset and is  $t_d = 155ms$ . In this time, the first watchdog pulse from the microcontroller is required. If the trigger pulse NTRIG occurs during this time, the time  $t_1$  starts immediately. If no trigger signal occurs during the time  $t_d$ , a watchdog reset with  $t_{NRES} = 4ms$  will reset the microcontroller after  $t_d = 155ms$  and the LH output transistor switches on. The times  $t_1$  and  $t_2$  have a fixed relationship. A trigger signal from the microcontroller is anticipated within the time frame of  $t_2 = 21.6ms$ . To avoid false triggering from glitches, the trigger pulse must be longer than  $t_{trigmin} > 200ns$ . This slope serves to restart the watchdog sequence. If the triggering signal fails in this open window  $t_2$ , the NRES output is drawn to ground as well as the LH output. A trigger signal during the closed window  $t_1$  immediately switches NRES and LH to low.

Figure 4-15. Timing Sequence with  $R_{WDOSC} = 51k\Omega$



#### 4.6.2 Worst-Case Calculation with $R_{WDOSC} = 51k\Omega$

The internal oscillator has a tolerance of 20%. This means that  $t_1$  and  $t_2$  can also vary by 20%. The worst-case calculation for the watchdog period  $t_{wd}$  is calculated as follows. The ideal watchdog time  $t_{wd}$  is between the maximum  $t_1$  and the minimum  $t_1$  plus the minimum  $t_2$ .

$$t_{1,min} = 0.8 \times t_1 = 16.5ms, t_{1,max} = 1.2 \times t_1 = 24.8ms$$

$$t_{2,min} = 0.8 \times t_2 = 17.3ms, t_{2,max} = 1.2 \times t_2 = 26ms$$

$$t_{wdmax} = t_{1,min} + t_{2,min} = 16.5ms + 17.3ms = 33.8ms$$

$$t_{wdmin} = t_{1,max} = 24.8ms$$

$$t_{wd} = 29.3ms \pm 4.5ms (\pm 15\%)$$

A microcontroller with an oscillator tolerance of  $\pm 15\%$  is sufficient to supply the trigger inputs correctly.

**Table 4-4. Typical Watchdog Timings**

$R_{WDOSC}$ k $\Omega$	Oscillator Period $t_{osc}/\mu s$	Lead Time $t_d/ms$	Closed Window $t_1/ms$	Open Window $t_2/ms$	Trigger Period from Microcontroller $t_{wd}/ms$	Reset Time $t_{nres}/ms$
34	$13.3 \times 2$	105	14.0	14.7	19.9	4
51	$19.61 \times 2$	154.8	20.64	21.67	29.32	4
91	$3.54 \times 2$	264.80	35.32	37.06	50.14	4
120	$42.84 \times 2$	338.22	45.11	47.34	64.05	4

If the WDOSC pin has a short circuit to GND or the external resistor at the WDOSC pin is disconnected, the watchdog runs with an internal oscillator and guarantees a reset and activation of the LH output.

## 5. Absolute Maximum Ratings

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Parameters	Symbol	Min.	Typ.	Max.	Unit
Supply voltage $V_{VS}$ - DC voltage - $T_a = 25^\circ\text{C}$ , $t_{\text{Pulse}} \leq 500\text{ms}$ , $I_{VCC} \leq 85\text{mA}$ - $T_a = 25^\circ\text{C}$ , $t_{\text{Pulse}} \leq 2\text{min}$ , $I_{VCC} \leq 85\text{mA}$	$V_{VS}$	-0.3		+40 +43.5 +28	V
Logic pin voltage levels (TXD, RXD, EN, HSin, MODE, WDOSC, NRES, NTRIG)	$V_{\text{LOGIC}}$	-0.3		+5.5	V
Logic pin output DC currents	$I_{\text{LOGIC}}$	-5		+5	mA
LIN bus levels $V_{\text{LIN}}$ - DC voltage - Pulse time $\leq 500\text{ms}$	$V_{\text{LIN}}$	-27		+40 +43.5	V V
$V_{CC}$ - DC voltage - DC input current	$V_{VCC}$ $I_{VCC}$	-0.3		+5.5 +200	V mA
Logic level pins injection currents - DC currents - $t_{\text{Pulse}} \leq 2\text{min}$	$I_{\text{LOGIC}}$	-5 -5		0.1 +5	mA
LH voltage levels	$V_{\text{LH}}$	-0.3		$V_{VS} + 0.3$	V
HSout - DC voltage - DC output current - DC current injection levels $V_{\text{HSout}} < 0\text{V}$ and $V_{\text{HSout}} > V_{VS}$	$V_{\text{HSout}}$ $I_{\text{HSout}}$ $I_{\text{HSout}}$	-0.3 -50 -20		$V_{VS} + 0.3$  +10	V mA mA
CL15 voltage levels - DC voltage	$V_{\text{CL15}}$	-0.3		+40	V
WKin voltage levels - DC voltage - Transient voltage according to ISO7637 (coupling 1nF), (with 2.7K serial resistor)	$V_{\text{WKin}}$	-0.3 -150		+40 +100	V
ESD according to IBEE LIN EMC Test spec. 1.0 following IEC 61000-4-2 - Pin VS, WKin and LIN to GND (CL15 and WKin with ext. circuitry according to applications diagram)		$\pm 6$			kV
ESD according to ISO10605, with 330pF/330 $\Omega$ - Pin HSout (100 $\Omega$ series resistor, 22nF to GND) to GND		$\pm 6$			kV
ESD (HBM following STM5.1 with 1.5k $\Omega$ /100pF) - Pin VS, LIN, WKin, HSout, CL15 to GND		$\pm 6$			kV
Component level ESD (HBM according to ANSI/ESD STM5.1) JESD22-A114 AEC-Q100 (002)		$\pm 3$			kV
CDM ESD STM 5.3.1		$\pm 750$			V
ESD machine model AEC-Q100-RevF(003)		$\pm 100$			V
Junction temperature	$T_j$	-40		+150	$^\circ\text{C}$
Storage temperature	$T_s$	-55		+150	$^\circ\text{C}$

## 6. Thermal Characteristics

Parameters	Symbol	Min.	Typ.	Max.	Unit
Thermal resistance junction to heat slug	$R_{thjc}$		8		K/W
Thermal resistance junction to ambient, where heat slug is soldered to PCB according to JEDEC	$R_{thja}$		45		K/W
Thermal shutdown of $V_{VCC}$ regulator	$T_{VCCoff}$	150	165	180	°C
Thermal shutdown of LIN output	$T_{LINoff}$	150	165	180	°C
Thermal shutdown of high-side driver	$T_{DSoff}$	150	165	180	°C
Thermal shutdown hysteresis	$T_{hys}$		10		°C

## 7. Electrical Characteristics

$5V < V_{VS} < 28V$ ,  $-40^{\circ}C < T_j < 150^{\circ}C$ ; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
1	VS pin								
1.1	Nominal DC voltage range		VS	$V_{VS}$	5	13.5	28	V	A
1.2	Supply current in sleep mode	Sleep mode $V_{LIN} > V_{VS} - 0.5V$ $V_{VS} < 14V$ , $T = 27^{\circ}C$	VS	$I_{VSSleep}$	5	10	15	$\mu A$	B
		Sleep mode $V_{LIN} > V_{VS} - 0.5V$ $V_{VS} < 14V$	VS	$I_{VSSleep}$	3	11	18	$\mu A$	A
		Sleep mode, $V_{LIN} = 0V$ Bus shorted to GND $V_{VS} < 14V$	VS	$I_{VSSleep\_short}$	20	50	100	$\mu A$	A
1.3	Supply current in silent mode	Bus recessive $5.5V < V_{VS} < 14V$ , HS-driver off without load at VCC $T = 27^{\circ}C$	VS	$I_{VSSilent}$	30	47	58	$\mu A$	B
		Bus recessive $5.5V < V_{VS} < 14V$ , HS-driver off without load at VCC	VS	$I_{VSSilent}$	30	50	64	$\mu A$	A
		Bus recessive $V_{VS} < 5.5V$ , $V_{VCC} > V_{VCC\_th\_uv}$ HS-driver off without load at VCC	VS	$I_{VSSilent}$	30	150	190	$\mu A$	A
		Silent mode $5.5V < V_{VS} < 14V$ , HS-driver off without load at VCC Bus shorted to GND	VS	$I_{VSSilent\_short}$	50	90	130	$\mu A$	A
1.4	Supply current in normal mode	Bus recessive $V_{VS} < 14V$ , HS-driver off without load at VCC, watchdog on, $51k\Omega$ at WDOSC	VS	$I_{VSrec}$	300	400	500	$\mu A$	A
		Bus recessive $V_{VS} < 14V$ , HS-driver off without load at VCC, watchdog off ( $V_{MODE} = V_{VCC}$ )	VS	$I_{VSrec}$	150	250	350	$\mu A$	A

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>j</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
1.5	Supply current in normal mode	Bus dominant (internal LIN pull-up resistor active) V <sub>VS</sub> < 14V, HS-driver off without load at VCC, watchdog on, 51kΩ at WDOSC	VS	I <sub>VSdom</sub>	600	900	1150	μA	A
		Bus dominant (internal LIN pull-up resistor active) V <sub>VS</sub> < 14V, HS-driver off without load at VCC, watchdog off (V <sub>MODE</sub> = V <sub>VCC</sub> )	VS	I <sub>VSdom</sub>	500	750	1000	μA	A
1.6	Supply current in fail-safe mode	Bus recessive 5.5V < V <sub>VS</sub> < 14V, HS-driver off without load at VCC, watchdog on, 51kΩ at WDOSC	VS	I <sub>VSfail</sub>	100	200	300	μA	A
		Bus recessive 5.5V < V <sub>VS</sub> < 14V, HS-driver off without load at VCC, watchdog off (V <sub>MODE</sub> = V <sub>VCC</sub> )	VS	I <sub>VSfail</sub>	40	70	100	μA	A
		Bus recessive 2V < V <sub>VS</sub> < 5.5V, HS-driver off without load at VCC watchdog on, 51kΩ at WDOSC	VS	I <sub>VSfail</sub>	150	280	320	μA	A
		Bus recessive 2V < V <sub>VS</sub> < 5.5V, HS-driver off without load at VCC watchdog off (V <sub>MODE</sub> = V <sub>VCC</sub> )	VS	I <sub>VSfail</sub>	50	150	200	μA	A
1.7	VS undervoltage threshold (switching from normal mode to fail-safe mode)	Decreasing supply voltage	VS	V <sub>VS_th_N_F_down</sub>	3.9	4.3	4.7	V	A
		Increasing supply voltage	VS	V <sub>VS_th_F_N_up</sub>	4.1	4.6	4.9	V	A
1.8	VS undervoltage hysteresis		VS	V <sub>VS_hys_F_N</sub>	0.1	0.25	0.4	V	A
1.9	VS operation threshold (switching to unpowered mode)	Switch to unpowered mode	VS	V <sub>VS_th_U_down</sub>	1.9	2.05	2.3	V	A
		Switch from unpowered mode to fail-safe mode	VS	V <sub>VS_th_U_F_up</sub>	2.0	2.25	2.4	V	A
1.10	VS undervoltage hysteresis		VS	V <sub>VS_hys_U</sub>	0.1	0.2	0.3	V	A
<b>2 RXD output pin</b>									
2.1	Low-level output sink capability	Normal mode, V <sub>LIN</sub> = 0V, I <sub>RXD</sub> = 2mA	RXD	V <sub>RXDL</sub>		0.2	0.4	V	A
2.2	High-level output source capability	Normal mode V <sub>LIN</sub> = V <sub>S</sub> , I <sub>RXD</sub> = -2mA	RXD	V <sub>RXDH</sub>	V <sub>CC</sub> - 0.4V	V <sub>CC</sub> - 0.2V		V	A
<b>3 TXD input/output pin</b>									
3.1	Low-level voltage input		TXD	V <sub>TXDL</sub>	-0.3		+0.8	V	A
3.2	High-level voltage input		TXD	V <sub>TXDH</sub>	2		V <sub>CC</sub> + 0.3V	V	A
3.3	Pull-up resistor	V <sub>TXD</sub> = 0V	TXD	R <sub>TXD</sub>	40	70	100	kΩ	A
3.4	High-level leakage current	V <sub>TXD</sub> = V <sub>CC</sub>	TXD	I <sub>TXD</sub>	-3		+3	μA	A

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>J</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
3.5	Low-level output sink current at wake-up request	Fail-safe mode V <sub>LIN</sub> = V <sub>VS</sub> V <sub>Wkin</sub> = 0V V <sub>TXD</sub> = 0.4V	TXD	I <sub>TXD</sub>	2	2.5	8	mA	A
<b>4 EN input pin</b>									
4.1	Low-level voltage input		EN	V <sub>ENL</sub>	-0.3		+0.8	V	A
4.2	High-level voltage input		EN	V <sub>ENH</sub>	2		V <sub>CC</sub> + 0.3V	V	A
4.3	Pull-down resistor	V <sub>EN</sub> = V <sub>VCC</sub>	EN	R <sub>EN</sub>	50	125	200	kΩ	A
4.4	Low-level input current	V <sub>EN</sub> = 0V	EN	I <sub>EN</sub>	-3		+3	μA	A
<b>5 NRES open drain output pin</b>									
5.1	Low-level output voltage	V <sub>VS</sub> ≥ 5.5V I <sub>NRES</sub> = 2mA	NRES	V <sub>NRESL</sub>		0.2	0.4	V	A
5.2	Undervoltage reset time	V <sub>VS</sub> ≥ 5.5V C <sub>NRES</sub> = 20pF	NRES	t <sub>Reset</sub>	2	4	6	ms	A
5.3	Reset debounce time for falling edge	V <sub>VS</sub> ≥ 5.5V C <sub>NRES</sub> = 20pF	NRES	t <sub>res_f</sub>	0.5		10	μs	A
5.4	Switch-off leakage current	V <sub>NRES</sub> = 5.5V	NRES	I <sub>NRES_L</sub>	-3		+3	μA	A
<b>6 VCC voltage regulator ATA663431</b>									
6.1	Output voltage VCC	4V < V <sub>VS</sub> < 18V (0mA to 50mA)	VCC	V <sub>VCCnor</sub>	3.234		3.366	V	A
		4.5V < V <sub>VS</sub> < 18V (0mA to 85mA)	VCC	V <sub>VCCnor</sub>	3.234		3.366	V	C
6.2	Output voltage V <sub>VCC</sub> at low V <sub>VS</sub>	3V < V <sub>VS</sub> < 4V	VCC	V <sub>VCClow</sub>	V <sub>VS</sub> - V <sub>D</sub>		3.366	V	A
6.3	Regulator drop voltage	V <sub>VS</sub> > 3V, I <sub>VCC</sub> = -15mA	VCC	V <sub>D1</sub>		200	250	mV	A
6.4	Regulator drop voltage	V <sub>VS</sub> > 3V, I <sub>VCC</sub> = -50mA	VCC	V <sub>D2</sub>		300	500	mV	A
6.5	Line regulation maximum	4V < V <sub>VS</sub> < 18V	VCC	V <sub>VCCline</sub>		0.1	0.2	%	A
6.6	Load regulation maximum	5mA < I <sub>VCC</sub> < 50mA	VCC	V <sub>VCCload</sub>		0.1	0.5	%	A
6.7	Output current limitation	V <sub>VS</sub> > 4V	VCC	I <sub>VCClim</sub>		-180	-120	mA	A
6.8	Load capacity	MLC capacitor	VCC	C <sub>load</sub>	1.8	2.2		μF	D
6.9	VCC undervoltage threshold (NRES ON)	Referred to VCC V <sub>VS</sub> > 4V	VCC	V <sub>VCC_th_uv_dow n</sub>	2.4	2.6	2.8	V	A
	VCC undervoltage threshold (NRES OFF)	Referred to VCC V <sub>VS</sub> > 4V	VCC	V <sub>VCC_th_uv_up</sub>	2.5	2.7	2.9	V	A
6.10	Hysteresis of VCC undervoltage threshold	Referred to VCC V <sub>VS</sub> > 4V	VCC	V <sub>VCC_hys_uv</sub>	100	200	300	mV	A
6.11	Ramp-up time V <sub>VS</sub> > 4V to VCC = 3.3V	C <sub>VCC</sub> = 2.2μF I <sub>load</sub> = -5mA at VCC	VCC	t <sub>VCC</sub>		1	1.5	ms	A

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>J</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
<b>7 VCC voltage regulator ATA663454</b>									
7.1	Output voltage VCC	5.5V < V <sub>VS</sub> < 18V (0mA to 50mA)	VCC	V <sub>VCCnor</sub>	4.9		5.1	V	A
		6V < V <sub>VS</sub> < 18V (0mA to 85mA)	VCC	V <sub>VCCnor</sub>	4.9		5.1	V	C
7.2	Output voltage V <sub>CC</sub> at low V <sub>VS</sub>	4V < V <sub>VS</sub> < 5.5V	VCC	V <sub>VCClow</sub>	V <sub>VS</sub> - V <sub>D</sub>		5.1	V	A
7.3	Regulator drop voltage	V <sub>VS</sub> > 4V, I <sub>VCC</sub> = -20mA	VCC	V <sub>D1</sub>		100	200	mV	A
7.4	Regulator drop voltage	V <sub>VS</sub> > 4V, I <sub>VCC</sub> = -50mA	VCC	V <sub>D2</sub>		300	500	mV	A
7.5	Regulator drop voltage	V <sub>VS</sub> > 3.3V, I <sub>VCC</sub> = -15mA	VCC	V <sub>D3</sub>			150	mV	A
7.6	Line regulation maximum	5.5V < V <sub>VS</sub> < 18V	VCC	V <sub>VCCline</sub>		0.1	0.2	%	A
7.7	Load regulation maximum	5mA < I <sub>VCC</sub> < 50mA	VCC	V <sub>VCCload</sub>		0.1	0.5	%	A
7.8	Output current limitation	V <sub>VS</sub> > 5.5V	VCC	I <sub>VCClim</sub>		-180	-120	mA	A
7.9	Load capacity	MLC capacitor	VCC	C <sub>load</sub>	1.8	2.2		μF	D
7.10	VCC undervoltage threshold (NRES ON)	Referred to VCC V <sub>VS</sub> > 4V	VCC	V <sub>VCC_th_uv_down</sub> <sub>n</sub>	4.2	4.4	4.6	V	A
	VCC undervoltage threshold (NRES OFF)	Referred to VCC V <sub>VS</sub> > 4V	VCC	V <sub>VCC_th_uv_up</sub>	4.3	4.6	4.8	V	A
7.11	Hysteresis of undervoltage threshold	Referred to VCC V <sub>VS</sub> > 5.5V	VCC	V <sub>VCC_hys_uv</sub>	100	200	300	mV	A
7.12	Ramp-up time V <sub>VS</sub> > 5.5V to VCC = 5V	C <sub>VCC</sub> = 2.2μF I <sub>load</sub> = -5mA at VCC	VCC	t <sub>VCC</sub>		1	1.5	ms	A
<b>8 LIN bus driver: bus load conditions:</b>									
Load 1 (Small): 1nF, 1kΩ; Load 2 (Large): 10nF, 500Ω; C <sub>RXD</sub> = 20pF, Load 3 (Medium): 6.8nF, 660Ω characterized on samples 10.7 and 10.8 specifies the timing parameters for proper operation at 20kb/s and 10.9kb/s and 10.10kb/s at 10.4kb/s									
8.1	Driver recessive output voltage	Load1/Load2	LIN	V <sub>BUSrec</sub>	0.9 × V <sub>VS</sub>		V <sub>VS</sub>	V	A
8.2	Driver-dominant voltage	V <sub>VS</sub> = 7V R <sub>load</sub> = 500Ω	LIN	V <sub>LoSUP</sub>			1.2	V	A
8.3	Driver-dominant voltage	V <sub>VS</sub> = 18V R <sub>load</sub> = 500Ω	LIN	V <sub>HiSUP</sub>			2	V	A
8.4	Driver-dominant voltage	V <sub>VS</sub> = 7V R <sub>load</sub> = 1000Ω	LIN	V <sub>LoSUP_1k</sub>	0.6			V	A
8.5	Driver-dominant voltage	V <sub>VS</sub> = 18V R <sub>load</sub> = 1000Ω	LIN	V <sub>HiSUP_1k</sub>	0.8			V	A
8.6	Pull-up resistor to V <sub>VS</sub>	The serial diode is mandatory	LIN	R <sub>LIN</sub>	20	30	47	kΩ	A
8.7	Voltage drop at the serial diodes	In pull-up path with R <sub>slave</sub> I <sub>SerDiode</sub> = 10mA	LIN	V <sub>SerDiode</sub>	0.4		1.0	V	D
8.8	LIN current limitation V <sub>BUS</sub> = V <sub>Bat_max</sub>		LIN	I <sub>BUS_LIM</sub>	40	120	200	mA	A
8.9	Input leakage current at the receiver including pull-up resistor as specified	Input leakage current Driver off V <sub>BUS</sub> = 0V V <sub>VS</sub> = 12V	LIN	I <sub>BUS_PAS_dom</sub>	-1	-0.35		mA	A

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>J</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
8.10	Leakage current LIN recessive	Driver off 8V < V <sub>VS</sub> < 18V 8V < V <sub>BUS</sub> < 18V V <sub>BUS</sub> ≥ V <sub>Bat</sub>	LIN	I <sub>BUS_PAS_rec</sub>		10	20	μA	A
8.11	Leakage current when control unit disconnected from ground. Loss of local ground must not affect communication in the residual network	GND <sub>Device</sub> = V <sub>VS</sub> V <sub>VS</sub> = 12V 0V < V <sub>BUS</sub> < 18V	LIN	I <sub>BUS_NO_gnd</sub>	-10	+0.5	+10	μA	A
8.12	Leakage current at disconnected battery. Node has to sustain the current that can flow under this condition. Bus must remain operational under this condition.	V <sub>VS</sub> disconnected V <sub>SUP_Device</sub> = GND 0V < V <sub>BUS</sub> < 18V	LIN	I <sub>BUS_NO_bat</sub>		0.1	2	μA	A
8.13	Capacitance on the LIN pin to GND		LIN	C <sub>LIN</sub>			20	pF	D
<b>9 LIN bus receiver</b>									
9.1	Center of receiver threshold	V <sub>BUS_CNT</sub> = (V <sub>th_dom</sub> + V <sub>th_rec</sub> )/2	LIN	V <sub>BUS_CNT</sub>	0.475 × V <sub>VS</sub>	0.5 × V <sub>VS</sub>	0.525 × V <sub>VS</sub>	V	A
9.2	Receiver dominant state	V <sub>EN</sub> = 5V/3.3V	LIN	V <sub>BUSdom</sub>	-27		0.4 × V <sub>VS</sub>	V	A
9.3	Receiver recessive state	V <sub>EN</sub> = 5V/3.3V	LIN	V <sub>BUSrec</sub>	0.6 × V <sub>VS</sub>		40	V	A
9.4	Receiver input hysteresis	V <sub>hys</sub> = V <sub>th_rec</sub> - V <sub>th_dom</sub>	LIN	V <sub>BUShys</sub>	0.028 × V <sub>VS</sub>	0.1 × V <sub>VS</sub>	0.175 × V <sub>VS</sub>	V	A
9.5	Pre-wake detection LIN High-level input voltage		LIN	V <sub>LINH</sub>	V <sub>VS</sub> - 2V		V <sub>VS</sub> + 0.3V	V	A
9.6	Pre-wake detection LIN Low-level input voltage	Activates the LIN receiver	LIN	V <sub>LINL</sub>	-27		V <sub>VS</sub> - 3.3V	V	A
<b>10 Internal timers</b>									
10.1	Dominant time for wake-up via LIN bus	V <sub>LIN</sub> = 0V	LIN	t <sub>bus</sub>	50	100	150	μs	A
10.2	Time delay for mode change from fail-safe mode to normal mode via the EN pin	V <sub>EN</sub> = 5V/3.3V	EN	t <sub>norm</sub>	5	15	20	μs	A
10.3	Time delay for mode change from normal mode to Sleep Mode via the EN pin	V <sub>EN</sub> = 0V	EN	t <sub>sleep</sub>	5	15	20	μs	A
10.4	TXD-dominant time-out time	V <sub>TXD</sub> = 0V	TXD	t <sub>dom</sub>	20	40	60	ms	A
10.6	Time delay for mode change from silent mode to normal mode via the EN pin	V <sub>EN</sub> = 5V/3.3V	EN	t <sub>s_n</sub>	5	15	40	μs	A
10.7	Duty cycle 1	TH <sub>Rec(max)</sub> = 0.744 × V <sub>VS</sub> TH <sub>Dom(max)</sub> = 0.581 × V <sub>VS</sub> V <sub>VS</sub> = 7.0V to 18V t <sub>Bit</sub> = 50μs D1 = t <sub>bus_rec(min)</sub> / (2 × t <sub>Bit</sub> )	LIN	D1	0.396				A

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>J</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
10.8	Duty cycle 2	$TH_{Rec(min)} = 0.422 \times V_{VS}$ $TH_{Dom(min)} = 0.284 \times V_{VS}$ $V_{VS} = 7.6V \text{ to } 18V$ $t_{Bit} = 50\mu s$ $D2 = t_{bus\_rec(max)} / (2 \times t_{Bit})$	LIN	D2			0.581		A
10.9	Duty cycle 3	$TH_{Rec(max)} = 0.778 \times V_{VS}$ $TH_{Dom(max)} = 0.616 \times V_{VS}$ $V_{VS} = 7.0V \text{ to } 18V$ $t_{Bit} = 96\mu s$ $D3 = t_{bus\_rec(min)} / (2 \times t_{Bit})$	LIN	D3	0.417				A
10.10	Duty cycle 4	$TH_{Rec(min)} = 0.389 \times V_{VS}$ $TH_{Dom(min)} = 0.251 \times V_{VS}$ $V_{VS} = 7.6V \text{ to } 18V$ $t_{Bit} = 96\mu s$ $D4 = t_{bus\_rec(max)} / (2 \times t_{Bit})$	LIN	D4			0.590		A
10.11	Slope time falling and rising edge at LIN	$V_{VS} = 7.0V \text{ to } 18V$	LIN	$t_{SLOPE\_fall}$ $t_{SLOPE\_rise}$	3.5		22.5	$\mu s$	A
10.12	TXD release time after dominant time-out detection		TXD	$t_{DTOrel}$	10		20	$\mu s$	B
11	Receiver electrical AC parameters of the LIN physical layer LIN receiver, RXD load conditions: C <sub>RXD</sub> = 20pF								
11.1	Propagation delay of receiver	$V_{VS} = 7.0V \text{ to } 18V$ $t_{rx\_pd} = \max(t_{rx\_pdr}, t_{rx\_pdf})$	RXD	$t_{rx\_pd}$			6	$\mu s$	A
11.2	Symmetry of receiver propagation delay rising edge minus falling edge	$V_{VS} = 7.0V \text{ to } 18V$ $t_{rx\_sym} = t_{rx\_pdr} - t_{rx\_pdf}$	RXD	$t_{rx\_sym}$	-2		+2	$\mu s$	A
12	WKin pin								
12.1	High-level input voltage		WKin	$V_{WKinH}$	$V_{VS} - 1V$		$V_{VS} + 0.3V$	V	A
12.2	Low-level input voltage	Initializes a wake-up signal	WKin	$V_{WKinL}$	-1		$V_{VS} - 3.3V$	V	A
12.3	WKin pull-up current	$V_{VS} < 28V, V_{WKin} = 0V$	WKin	$I_{WKin}$	-30	-10		$\mu A$	A
12.4	High-level leakage current	$V_{VS} = 28V, V_{WKin} = 28V$	WKin	$I_{WKinL}$	-5		+5	$\mu A$	A
12.5	Debounce time of low pulse for wake-up via WKin pin	$V_{WKin} = 0V$	WKin	$t_{WKin}$	50	100	150	$\mu s$	A
13	Watchdog oscillator								
13.1	Voltage at WDOSC in normal or fail-safe mode	$I_{WD\_OSC} = -200\mu A$ $V_{VS} \geq 4V$	WDOSC	$V_{WDOSC}$	1.13	1.23	1.33	V	A
13.2	Possible values of resistor	Resistor $\pm 1\%$	WDOSC	$R_{WDOSC}$	34		120	k $\Omega$	D
13.3	Oscillator period	$R_{WDOSC} = 34k\Omega$		$t_{OSC}$	21.3	26.6	31.94	$\mu s$	A
13.6	Oscillator period	$R_{WDOSC} = 120k\Omega$		$t_{OSC}$	68.4	85.6	102.8	$\mu s$	A
13.7	Watchdog lead time after reset			$t_d$		3948		cycles	B
13.8	Watchdog closed window			$t_1$		527		cycles	B
13.9	Watchdog open window			$t_2$		553		cycles	B
13.10	Watchdog reset time NRES		NRES	$t_{nres}$	2	4	6	ms	B

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>j</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
<b>14 Watchdog trigger input Pin NTRIG</b>									
14.1	Low-level voltage input		NTRIG	V <sub>NTRIG_L</sub>	-0.3		0.3V <sub>VCC</sub>	V	A
14.2	High-level voltage input		NTRIG	V <sub>NTRIG_H</sub>	0.7V <sub>VCC</sub>		V <sub>VCC</sub> + 0.3	V	A
14.3	Pull-up resistor	V <sub>NTRIG</sub> = 0V	NTRIG	R <sub>NTRIG</sub>	125	250	400	K	A
14.4	Input leakage current	V <sub>NTRIG</sub> = V <sub>VCC</sub>	NTRIG	I <sub>NTRIGleakH</sub>			1	μA	A
14.5	Minimum trigger width	V <sub>NTRIG</sub> = V <sub>VCC</sub>	NTRIG	t <sub>trig</sub>	200			ns	D
<b>15 MODE PIN</b>									
15.1	Low-level input voltage		MODE	V <sub>MODE_L</sub>	-0.3		0.3V <sub>VCC</sub>	V	A
15.2	High-level input voltage		MODE	V <sub>MODE_H</sub>	0.7V <sub>VCC</sub>		V <sub>VCC</sub> + 0.3	V	A
15.4	Leakage current	V <sub>MODE</sub> = 0V or V <sub>MODE</sub> = V <sub>VCC</sub>	MODE	I <sub>MODE</sub>	-3		+3	μA	A
15.5	MODE pin pull-up current	V <sub>MODE</sub> = 0.7V <sub>VCC</sub>	MODE	I <sub>MODE_PU</sub>	-75		-5	μA	A
15.6	MODE pin pull-down current	V <sub>MODE</sub> = 0.3V <sub>VCC</sub>	MODE	I <sub>MODE_PD</sub>	5		75	μA	A
<b>16 Limp Home open drain failure output pin LH</b>									
16.1	Output drain-to-source on resistance	T <sub>j</sub> = 125°C	LH	R <sub>DSon,LH</sub>			50	Ω	A
16.2	Leakage current	V <sub>LH</sub> < 40V	LH	I <sub>leak,LH</sub>			2	μA	A
<b>17 HSout pin</b>									
17.1	Output drain-to-source on resistance	I <sub>HSout</sub> = -20mA	HSout	R <sub>DSon,HS</sub>			20	Ω	A
17.2	Leakage current	-0.2V < V <sub>HSout</sub> < V <sub>VS</sub> + 0.2V	HSout	I <sub>leak,HS</sub>			2	μA	A
17.5	Switch-off slope (fall time)	V <sub>VS</sub> = 16V R <sub>load</sub> = 560Ω C <sub>load</sub> = 1nF transition from 80% down to 20% of V <sub>VS</sub>	HSout	t <sub>HSslope,fall</sub>	0.75		5	μs	A
17.6	Switch-on slope (rise time)	V <sub>VS</sub> = 16V R <sub>load</sub> = 560Ω C <sub>load</sub> = 1nF transition from 20% to 80% of V <sub>VS</sub>	HSout	t <sub>HSslope,rise</sub>	0.75		5	μs	A
17.7	Switch-on delay	V <sub>VS</sub> = 16V R <sub>load</sub> = 560Ω C <sub>load</sub> = 1nF time from HSin=HIGH to V <sub>HSout</sub> = 50% of V <sub>VS</sub>	HSout	t <sub>HSdel</sub>	3		20	μs	A
17.8	Switch-off delay	V <sub>VS</sub> = 16V R <sub>load</sub> = 560Ω C <sub>load</sub> = 1nF time from HSin=LOW to V <sub>HSout</sub> = 50% of V <sub>VS</sub>	HSout	t <sub>HSdel</sub>	3		20	μs	A
17.9	Short-circuit detection threshold		HSout	V <sub>SCth_HS</sub>	V <sub>VS</sub> - 6V		V <sub>VS</sub> - 2V	V	A
17.10	Short-circuit deb. time		HSout	t <sub>HS_deb</sub>	2		10	μs	A

\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

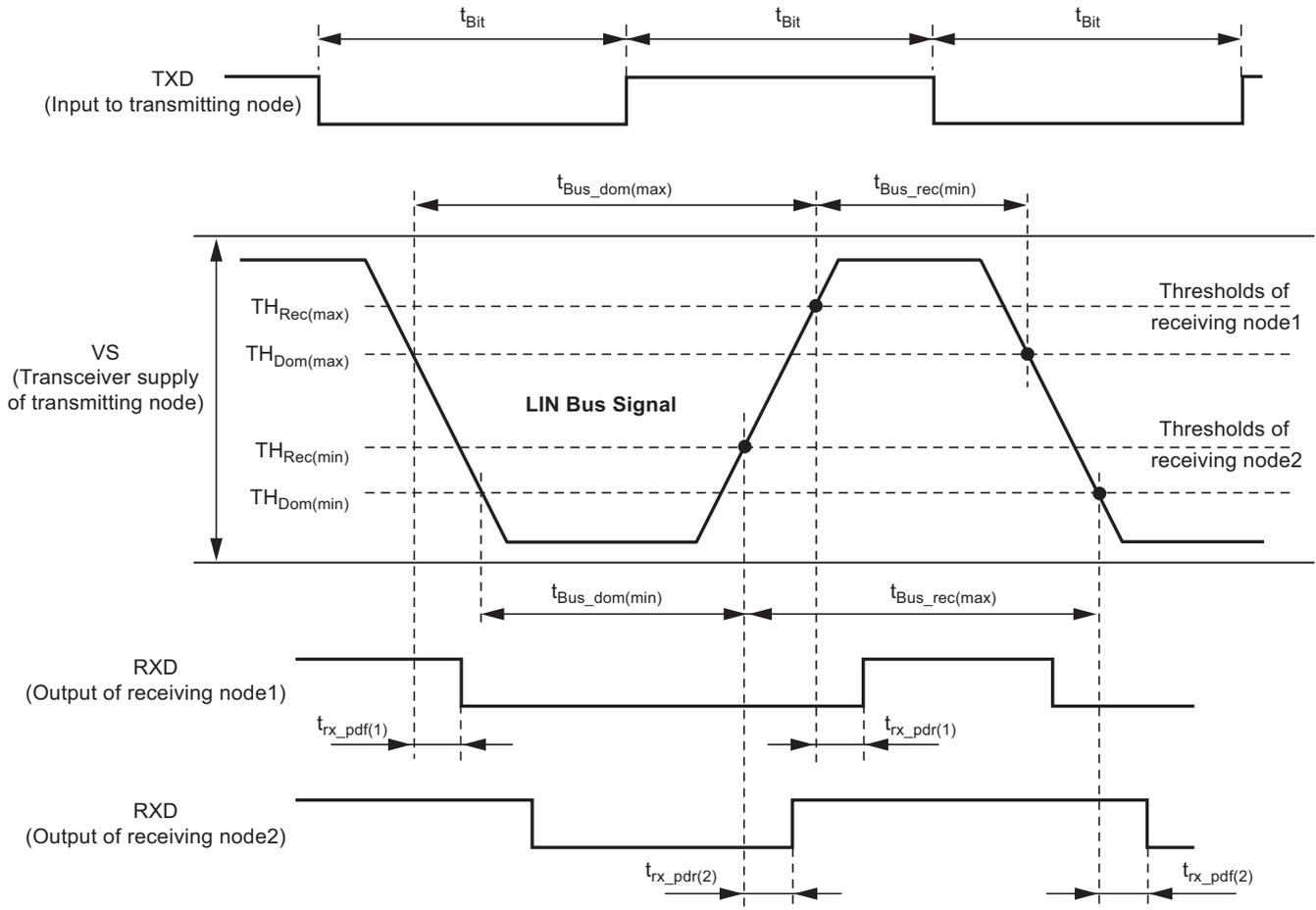
## 7. Electrical Characteristics (Continued)

5V < V<sub>VS</sub> < 28V, -40°C < T<sub>J</sub> < 150°C; unless otherwise specified all values refer to GND pins.

No.	Parameters	Test Conditions	Pin	Symbol	Min.	Typ.	Max.	Unit	Type*
<b>18 HSin pin</b>									
18.1	Low-level voltage input		HSin	V <sub>HSin_L</sub>	-0.3		0.3V <sub>VCC</sub>	V	A
18.2	High-level voltage input		HSin	V <sub>HSin_H</sub>	0.7V <sub>VCC</sub>		V <sub>VCC</sub> + 0.3	V	A
18.3	Pull-down resistor	V <sub>HSin</sub> = V <sub>VCC</sub>	HSin	R <sub>HSin</sub>	50	100	150	kΩ	A
18.4	Low-level input current	V <sub>HSin</sub> = 0V	HSin	I <sub>HSin</sub>	-1		+1	μA	A
18.5	Maximum switching frequency	R <sub>load</sub> = 560Ω	HSin	f <sub>HSin,max</sub>	5			kHz	D
<b>19 CL15 HV input pin</b>									
19.1	High Level input voltage	Positive edge initiates a local wake-up	CL15	V <sub>CL15H</sub>	4			V	A
19.2	Low level input voltage		CL15	V <sub>CL15L</sub>	-1		+2	V	A
19.3	Pull-down current	V <sub>VS</sub> < 28V, V <sub>CL15</sub> = 28V	CL15	I <sub>CL15</sub>		50	60	μA	A
19.4	Internal debounce time	Without external capacitor	CL15	t <sub>dbCL15</sub>	50	100	150	μs	A

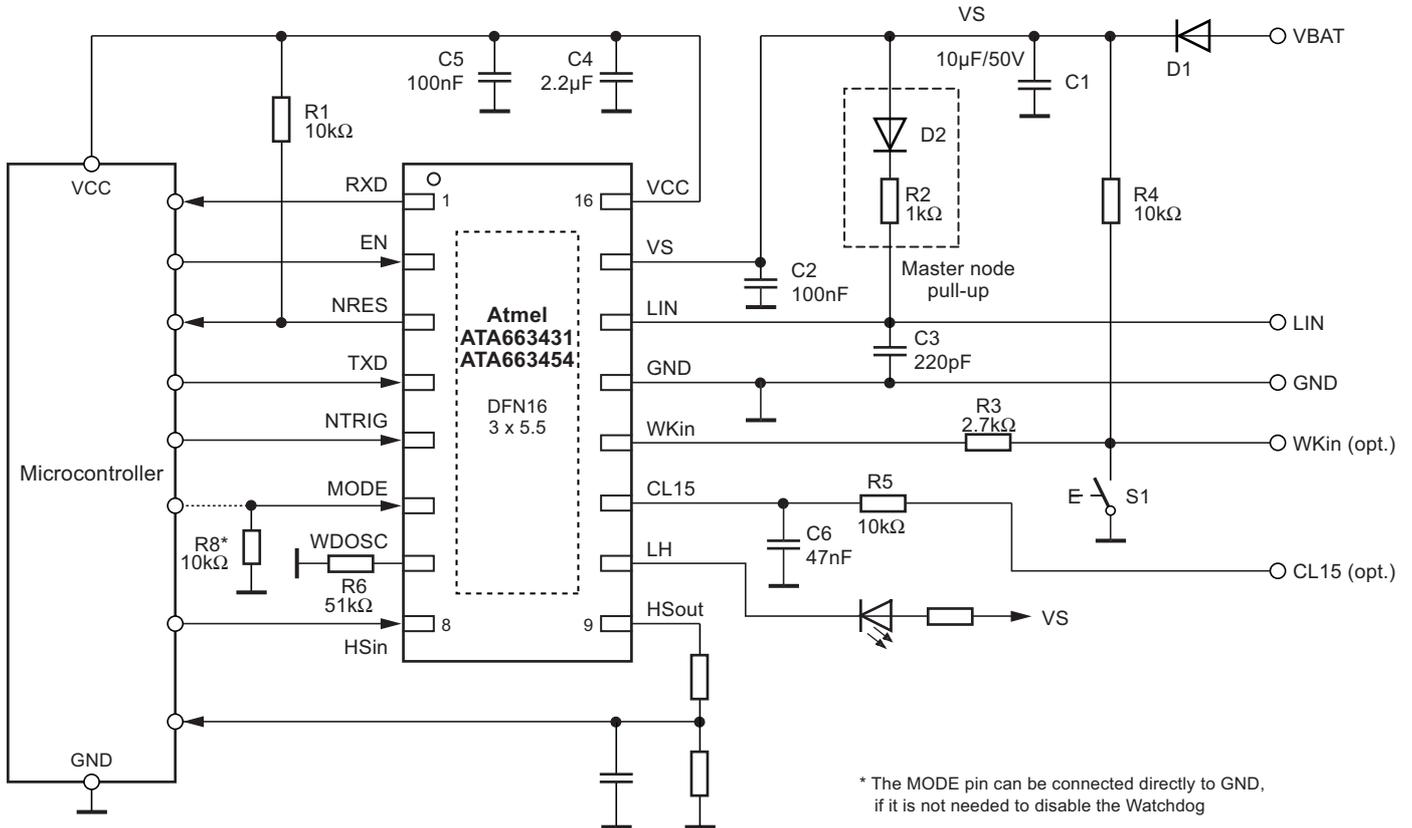
\*) Type means: A = 100% tested, B = 100% correlation tested, C = Characterized on samples, D = Design parameter

Figure 7-1. Definition of Bus Timing Characteristics



## 8. Application Circuits

Figure 8-1. Typical Application Circuit



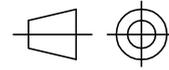
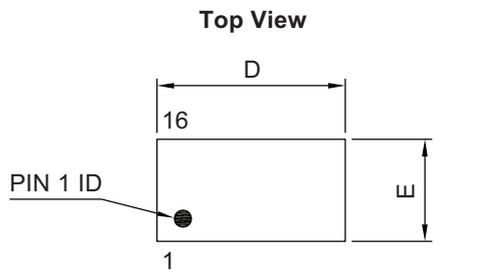
\* The MODE pin can be connected directly to GND, if it is not needed to disable the Watchdog

Note: Heat slug must always be connected to GND.

## 9. Ordering Information

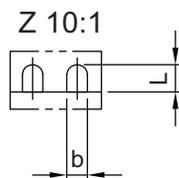
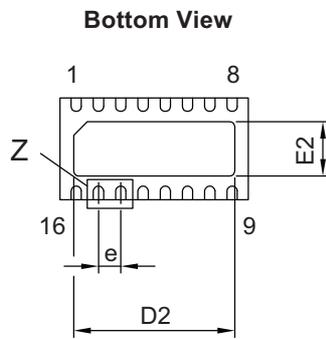
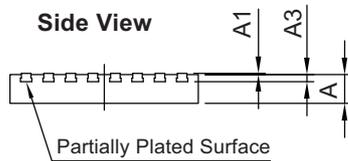
Extended Type Number	Package	Remarks
ATA663431-GDQW	DFN16	3.3V LIN system basis chip, Pb-free, 6k, taped and reeled
ATA663454-GDQW	DFN16	5V LIN system basis chip, Pb-free, 6k, taped and reeled

## 10. Package Information



technical drawings  
according to DIN  
specifications

Dimensions in mm  
Two Step Singulation process



COMMON DIMENSIONS				
(Unit of Measure = mm)				
Symbol	MIN	NOM	MAX	NOTE
A	0.8	0.85	0.9	
A1	0.0	0.035	0.05	
A3	0.16	0.21	0.26	
D	5.4	5.5	5.6	
D2	4.6	4.7	4.8	
E	2.9	3	3.1	
E2	1.5	1.6	1.7	
L	0.35	0.4	0.45	
b	0.25	0.3	0.35	
e		0.65		

10/11/13

**Atmel** Package Drawing Contact:  
packagedrawings@atmel.com

**TITLE**  
Package: VDFN\_5.5x3\_16L  
Exposed pad 4.7x1.6

**GPC**

**DRAWING NO.**

6.543-5168.01-4

**REV.**

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