AND8352

NCV7341 CAN Transceiver

Behavior with a Permanent Short on the CAN Bus

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APPLICATION NOTE

Introduction

This application note analyzes the behavior of a HS−CAN (= high−speed CAN) node in case a permanent short is present on the bus. Only shorts situated relatively close to the node are considered. If a very long bus wire is used (e.g. more than 20 m), a complex dynamic behavior can be encountered – signals will be reflected between the CAN node and the place of the short causing slightly different logical behavior on the transceiver−controller interface. However, the simplified case analyzed in this application note can be used as a sufficient approximation when especially quantifying the effect of a bus short on the current consumption of the transceiver.

At the beginning of the application note, the basic HS−CAN node structure is presented together with the signals on the transceiver−CAN controller interface both in case of working and faulty transmission. In the following parts, the measurements of signals and current consumptions on a real HS−CAN node are shown. The application note is concluded with a worst−case estimation of transceiver current consumptions.

Although all examples concern NCV7341 transceiver, the conclusions and data in this application note are equally relevant for other ON Semiconductor HS−CAN – namely AMIS−30660 and AMIS−42665. Only tiny numerical differences can be expected.

HS−CAN Node Architecture and Data Frame Format

For the purpose of this application note, the CAN node architecture depicted in Figure 1 is considered. The figure shows only the basic elements of the node relevant for our analysis; details of the bus termination are omitted and modeled by the equivalent 60 Ω resistor between bus lines.

Bus Signal in Case of a Fault−Free Bus

The used HS−CAN node firmware is set for a bus speed of 500 Kbps. If no other nodes are connected on the bus lines and no failure is present, the MCU periodically sends a fixed data frame shown in Figure 2. The data frame is sent every 73 bit times (1 bit time = 2 μs) and contains 32 dominant bits. The average bus traffic contains therefore ***44 % of dominant symbols and 56 % of recessive symbols***. The corresponding TxD signals are shown in Figure 3.

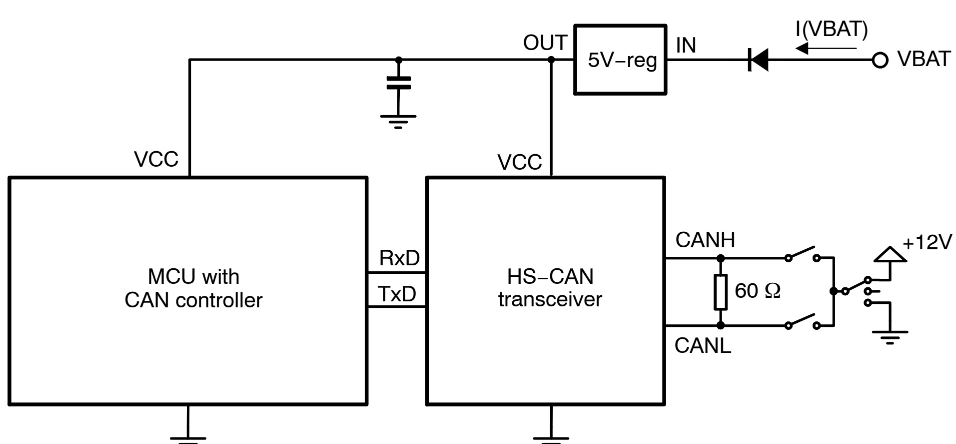

Figure 1. HS−CAN Node Architecture

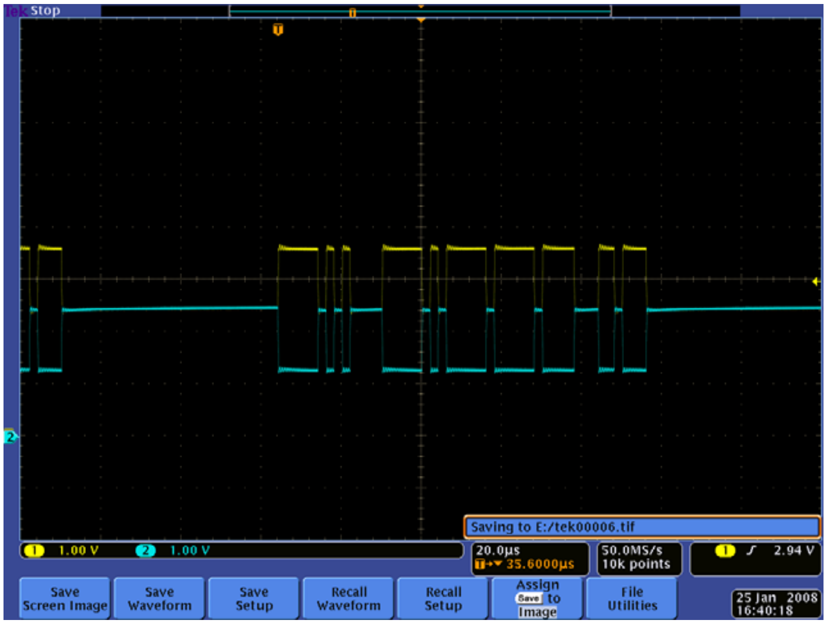

Figure 2. Data Frame Periodically Sent by the HS−CAN Node − Yellow Trace = CANH; Blue Trace = CANL

Figure 3. Data Frame Periodically Sent by the HS−CAN Node − Yellow Trace = TxD Signal Coming from the CAN Controller

Bus Signal in Case the Transmission is Not Possible

Under some of the considered failure−modes, the transmission to the bus is not possible (CANH shorted to ground, CANL shorted to 12 V, CANH shorted to CANL). The CAN controller is still trying to send the data frame requested by the MCU application software, but is not able to send any dominant symbol. The signal on the TxD pin leading from the CAN controller to the transceiver in this case is shown in Figures 4 and 5.

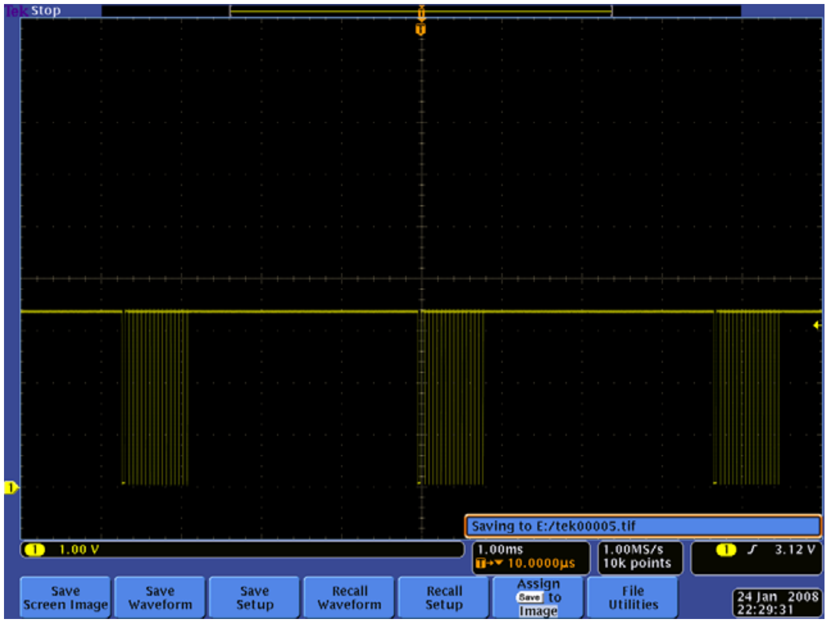

Figure 4. Signal on TxD Pin in Case No Transmission is Possible (Permanent Recessive on the Bus)

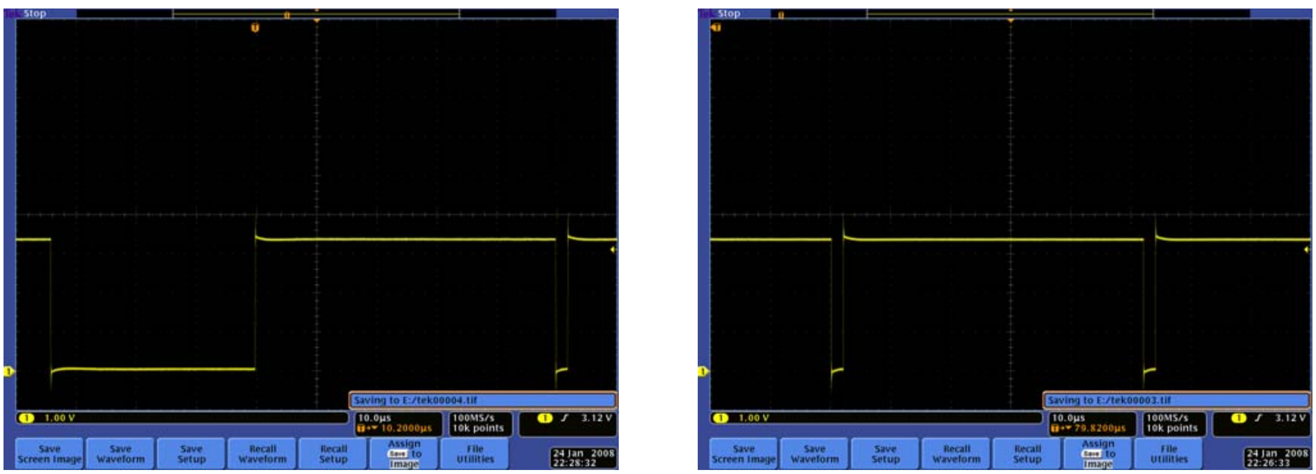

Figure 5. Signal on TxD Pin in Case No Transmission is Possible (Permanent Recessive on the Bus) – Zoomed to Different Parts of the Waveforms

One complete attempt of the CAN controller to send the data frame begins with a 17 dominant bits (see Figure 2) followed by 15 single−bit dominants interleaved with 25 recessive bits. The total length of the "burst" seen in Figure 4 is therefore 407 bits, out of which 32 are dominant.

After one unsuccessful attempt, the CAN controller stops any communication. In the HS−CAN node considered in this application note, the MCU software explicitly requires that the attempt is repeated as soon as possible. However, the CAN controller must wait 128 sequences of at least 11 recessive bits (requirement of the CAN protocol) before it re−starts the communication. It means that the "bursts" seen in Figure 4 are interleaved with 128 x 11 bit times of recessive.

In average, the ***TxD is low during only 2 % of the time***, when the transmission is not possible.

Relation to the CAN Protocol

TxD waveforms shown in Figures 4 and 5 are not specific to the considered test setup, but can be explained by the error−handling features of the CAN protocol, as defined by ISO11898−1 (data−link layer) under the assumption, that the bus remains permanently recessive due to a failure. The CAN controller goes through the following series of states (see Figure 6):

1. The transmitter starts in its "error active state", in which he can flag errors by a series of 6 dominant bits:
   a. the transmitter first tries to send the SOF bit (start of frame) – but it fails, as no dominant can be transmitted
   b. the transmitter tries to flag the failed SOF bit by a series of dominant bits – but it fails immediately at the 1st bit
   c. the transmitter ends up flagging "errors on errors" immediately after the first bits of each error flag – as none of the low levels on pin TxD results in a dominant symbol seen on the bus. Each of the encountered errors results in increase of the internal "transmit error counter" by 8 (c.f. the ISO norm for CAN).
   d. after, in total, 17 low level bits on TxD (SOF bit + 16 attempts to flag the error), the internal counter reaches a level higher than 128, at which the node becomes "error passive" and can't flag errors by dominant bits any more.
2. The transmitter continues in its "error passive state":
   e. an error is flagged by a series of 6 recessive flag bits followed by 8 recessive bits of an error delimiter and an inter frame space, composed of 3 bit intermission field and 8 more bits of "suspend transmission" bits – all of them recessive. Like that, an error results now in a series of 25 recessive bits (TxD high levels).
   f. after the first passive error flag together with the following recessive fields is over, the transmitter attempts again to start the frame by a dominant SOF bit – its failure is now flagged passively; each new attempt to send the SOF bit is therefore followed by 25 recessive bits. The internal "transmit error counter" is incremented by 8 after each failed SOF bit.
   g. After the internal counter reaches a value above 255, the CAN controller enters the "bus off" state, in which all communication is stopped
3. If the CAN controller settings allow it, the node can again re−start communication, but earliest after 128 series of 11 recessive bits detected on the bus – after this period, the CAN controller becomes again "error active".

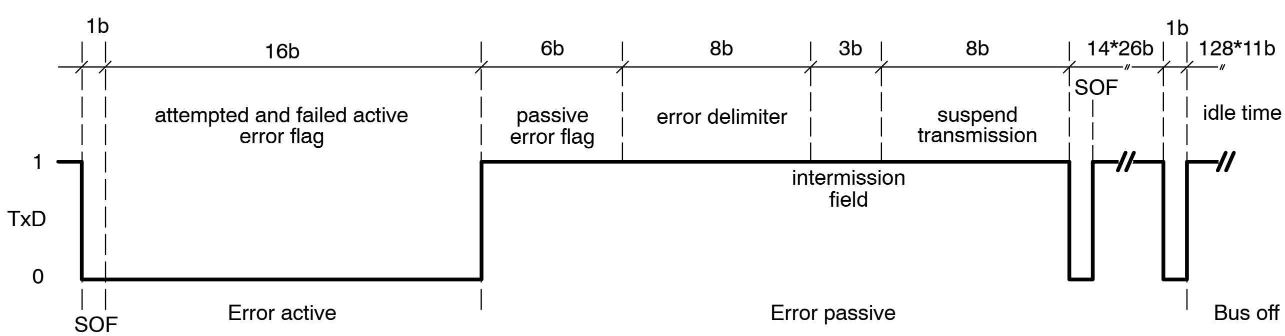

Figure 6. Activity of a Transmitting Node in Case No Transmission is Possible

Measurement Results of the Complete HS−CAN Node

The node shown in Figure 1 has been measured with different failure modes on the CAN bus (different types of shorts). The summary of the measurement results together with links to the scope pictures is given in Table 1. In the table, the overall node consumption is shown as measured directly on the node board connector by a multi−meter. Due to the supply filtering, we can consider the consumption values to represent the mathematical average. The 12 V source used to model some of the shorts is not included in the consumption.

Table 1. Overview of the CAN Bus Shorts and the Measured Node Consumptions

Bus Failure Mode	Consumption of the CAN Node I(VBAT) [mA]	Note
no failure	64.75	transmission works; normal voltage levels on the bus; see Figure 2
CANH shorted to ground	49.68	transmission not possible
CANL shorted to ground	71.56	transmission works; disturbed voltage levels on the bus; see Figure 7
CANH shorted to 12 V	49.80	transmission works; disturbed voltage levels on the bus; see Figure 8
CANL shorted to 12 V	47.94	transmission not possible
CANH shorted to CANL	46.71	transmission not possible

In most cases, the overall consumption of the CAN node drops. In case the transmission does not work any more, this consumption drop is due to the lower number of low level bits on TxD (c.a. 2% instead of 44%). Although the transceiver might consume more compared to the normal case when TxD = Low, its contribution to the average consumption is lower.

In case of the CANH shorted to 12 V, the transmission still works and the number of dominant bits does not change. The consumption of the transceiver is, however, lower, as the differential signal on the bus is driven purely by the low−side driver and the high−side driver current is zero.

Only when the CANL is shorted to ground, not only the transmission continues, but also the transceiver consumption increases, as the high−side driver current is now larger (the high−side driver now drives the 60 Ω termination resistor connected to ground with its second terminal).

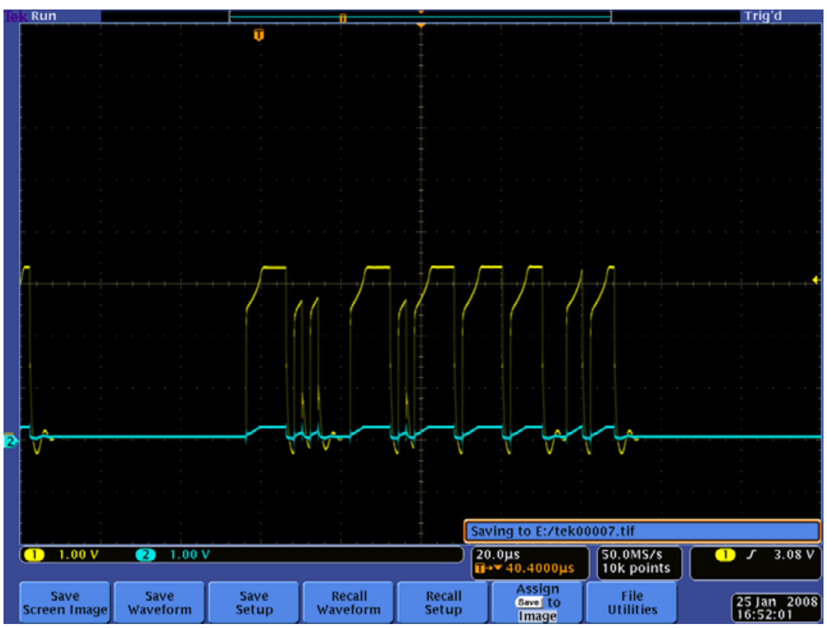

Figure 7. Data Frame Periodically Sent by the HS−CAN Node when CANL is Shorted to Ground − Yellow Trace = CANH; Blue Trace = CANL

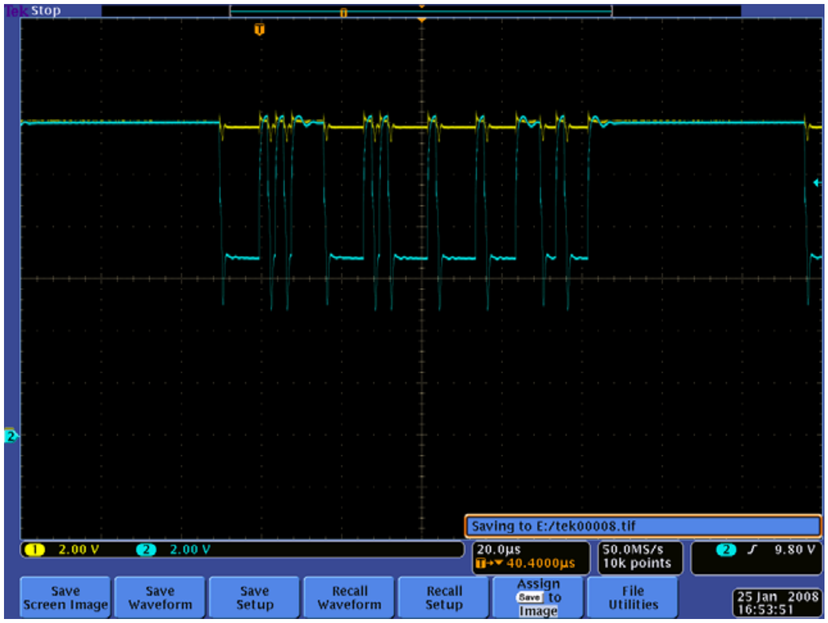

Figure 8. Data Frame Periodically Sent by the HS−CAN Node when CAHL is Shorted to 12 V – Yellow Trace = CANH; Blue Trace = CANL

Worst Case Consumption of the Transceiver

Based on the signal waveforms measured on the complete HS−CAN node, the consumption of the transceiver itself can be estimated. Table 3 shows the worst case consumption from VCC of NCV7341 transceiver, calculated from the datasheet parameters and the TxD signals measured on the full node. The relevant datasheet parameters are shown in Table 2

Table 2. NCV7341: Datasheet Parameters Used for the Worst−Case Current Consumption Calculation

			Min.	Typ.	Max.	Unit
I_{VCC}	V_{CC} current consumption	Normal mode V_{TxD} = 0 V, i.e. dominant	25	55	80	mA
		Normal mode V_{TxD} = V_{IO}, i.e. recessive or Receive−Only mode	2	6	10	mA
$V_{o(dom)}$ (CANH)	Dominant output voltage at pin CANH	V_{TxD} = 0 V	3.0	3.6	4.25	V
$I_{o(sc)}$ (CANH)	Short circuit output current at pin CANH	V_{CANH} = 0 V; V_{TxD} = 0 V	−45	−70	−120	mA

The transceiver consumption during TxD = High (recessive required) remains the same regardless whether the bus is fault−free or whether a short on the bus is encountered – it’s a consequence of the large common−mode voltage range in which the bus is not influenced by the transceiver.

The consumption during TxD = Low (dominant requested) strongly depends on the bus condition. When no failure is present, the consumption corresponds to the specified value I_{VCC}. When CANH or CANL is shorted to 12 V, the consumption during dominant can be taken equal to the recessive consumption, because no current is driven through the high−side driver. During mutual short of both bus wires and CANH short to ground, the additional consumption can be as high as the current limitation which therefore adds to the recessive consumption.

In the case when CANL is shorted to ground, CANH can be driven as high as the specified dominant voltage level Vo(dom)(CANH). This voltage is driven across the termination impedance of 60 Ω, determining the additional current consumption.

The recessive and dominant state current consumptions are averaged according the average time TxD is driven low by the CAN controller – 44% as long as the transmission works and only 2% when no transmission is possible.

Table 3. NCV7341: Worst Case Transceiver Consumption in Case for Different Types of Shorts on the Bus

Bus Failure Mode	Duty Cycle of TxD Low	Worst Case Transceiver Consumption I(VCC) [mA]			Explanation of I(VCC) During TxD = Low
		for TxD = High	for TxD = Low	Average	
no failure	44%	10	80	40.8	normal consumption
CANH shorted to ground	2%	10	130	12.4	recessive consumption + CANH current limitation
CANL shorted to ground	44%	10	81	41.2	recessive consumption + CANH voltage divided by 60 Ω
CANH shorted to VBAT	44%	10	10	10	equal to recessive consumption
CANL shorted to VBAT	2%	10	10	10	equal to recessive consumption
CANH shorted to CANL	2%	10	130	12.4	recessive consumption + CANH current limitation

Conclusion

If a short is present on the high−speed CAN bus, the bit stream on the TxD pin of the transceiver can be changed considerably because of the properties of the CAN protocol. It's therefore not sufficient to consider only the transceiver consumption during individual bits but also its contribution to the average. Both the measurements and the analysis have shown that the resulting average current consumptions in case of different types of bus shorts differ less than could be expected only from the datasheet parameters of the transceiver.

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