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INTEGRATED CIRCUITS – EMC EVALUATION OF CAN TRANSCEIVERS

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62228, which is a technical specification, has been prepared by subcommittee 47A: Integrated circuits, of IEC technical committee 47: Semiconductor devices.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
47A/747/DTS	47A/761/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an international standard;
- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTEGRATED CIRCUITS – EMC EVALUATION OF CAN TRANSCEIVERS

1 Scope

This document specifies test and measurement methods, test conditions, test setups, test procedures, failure criteria and test signals for the EMC evaluation of CAN transceivers concerning:

- the immunity against RF common mode disturbances on the signal lines,
- the emissions caused by non-symmetrical signals regarding the time and frequency domain,
- the immunity against transients (function and damage), and
- the immunity against electrostatic discharges – ESD (damage).

All measurements and functional tests except ESD are performed in a small (three transceiver) network. For ESD damage tests a single transceiver configuration on a special test board is used.

External protection circuits are not applied during the tests in order to get results for the transceiver IC only.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61967 (all parts), *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz*

IEC 61967-4, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 4: Measurement of conducted emissions – 1 Ω/150 Ω direct coupling method*

IEC 62132 (all parts), *Integrated circuits – Measurement of electromagnetic immunity, 150 kHz to 1 GHz*

IEC 62132-1, *Integrated circuits – Measurement of electromagnetic immunity, 150 kHz to 1 GHz – Part 1: General conditions and definitions*

IEC 62132-4, *Integrated circuits –Measurement of electromagnetic immunity 150 kHz to 1 GHz – Part 4: Direct RF Power Injection Method*

IEC 61000-4-2:1995, *Electromagnetic compatibility – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test*[1)]
Amendment 1 (1998)
Amendment 2 (2000)

ISO 7637-2: 2004, *Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only*

———————

[1)] A consolidated edition 1.2 exists, including IEC 61000-4-2:1995 and its Amendment 1 (1998) and Amendment 2 (2000)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61967 and IEC 62132 apply.

4 Measurements and tests

4.1 General

For evaluation of the EMC characteristic of CAN transceivers different test conditions and test set-ups are used:

– configuration of three powered transceivers in a CAN network for:
  - evaluation of narrowband emission at the bus lines and
  - evaluation of RF and transient immunity at the bus lines, voltage supply line V_{Bat} and the wake-up line;

– configuration of single unpowered transceiver for testing the damage immunity against ESD of the pins for bus lines, V_{Bat} and wake-up on a test board with functional required external components.

An overview of the requested measurements and tests is given in Table 1.

Table 1 – Overview of requested measurements and tests

Transceiver state	Required test	Test method	Evaluation	Transceiver mode
Active (powered)	RF emission	150 Ω direct coupling (IEC 61967-4)	Spectrum and asymmetry	Normal
	RF immunity	DPI (IEC 62132-4)	Function	Normal
				Stand by
				Sleep
	Transient immunity	Supply lines- direct galvanic coupling I/O lines- capacitive coupling Test pulse wave forms (ISO 7637-2)	Function	Normal
				Stand by
				Sleep
			Damage	Normal
Passive (unpowered)	ESD	Contact discharge (IEC 61000-4-2)	Damage	Normal

In order to reduce the effort for the characterization and to increase the compatibility of the results of different transceiver types, the number of test methods is defined to a necessary minimum. The 150 Ω direct coupling, DPI and direct galvanic and capacitive coupling methods are chosen for the evaluation of the EMC characteristic of active transceivers in a network configuration with three CAN nodes. While using a conductive decoupling and coupling, these three test methods are based on the same approach. Thus it is possible to use the same PCB for all required active/functional tests and measurements. These tests can be performed on the same test board in a common test configuration and set-up.

To get more reproducible test results, all measurement and tests should be done with soldered transceivers.

The described test conditions, configurations and test procedures are based on present stand-alone CAN transceivers. In case of ASICs with an integrated CAN transceiver, the test conditions cannot be defined completely for any type of IC. If it is possible, the test conditions of stand-alone CAN transceivers should be used. The configuration of the physical layer of the CAN bus should be the same.

4.2 RF and transient tests

4.2.1 General test conditions and configurations

4.2.1.1 Test conditions

The general test conditions are given in Table 2:

Table 2 – General test conditions

Parameter	Value
Voltage supply V_{Bat}	(14 ± 0,2) V
Voltage supply V_{CC}	(5 ± 0,1) V (default)
Voltage supply V_{IO}	(5 ± 0,1) V (default)
Test temperature	(23 ± 5) °C

The ambient noise floor for emission measurements shall be below the expected signal noise and shall be documented in the test report.

4.2.1.2 Test configuration

For the transceiver EMC analysis, a minimum network of three bus nodes has to be set up according to Figure 1.

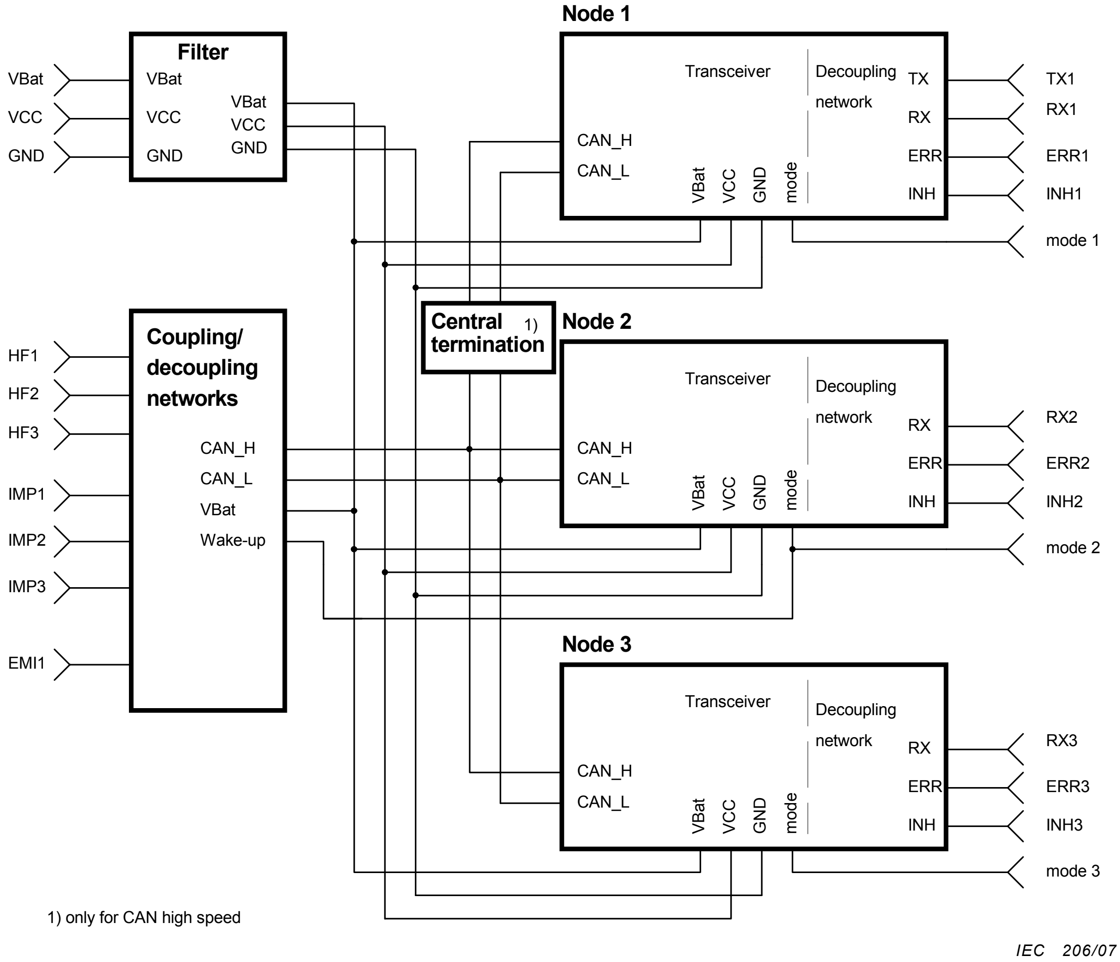

Figure 1 – Overview of a minimum configuration of a CAN system for emission and immunity tests against transient and RF disturbances

An example of a test circuit diagram for filter and the transceiver network for CAN high speed systems is given in Figure 2 and for CAN low speed systems in Figure 3.

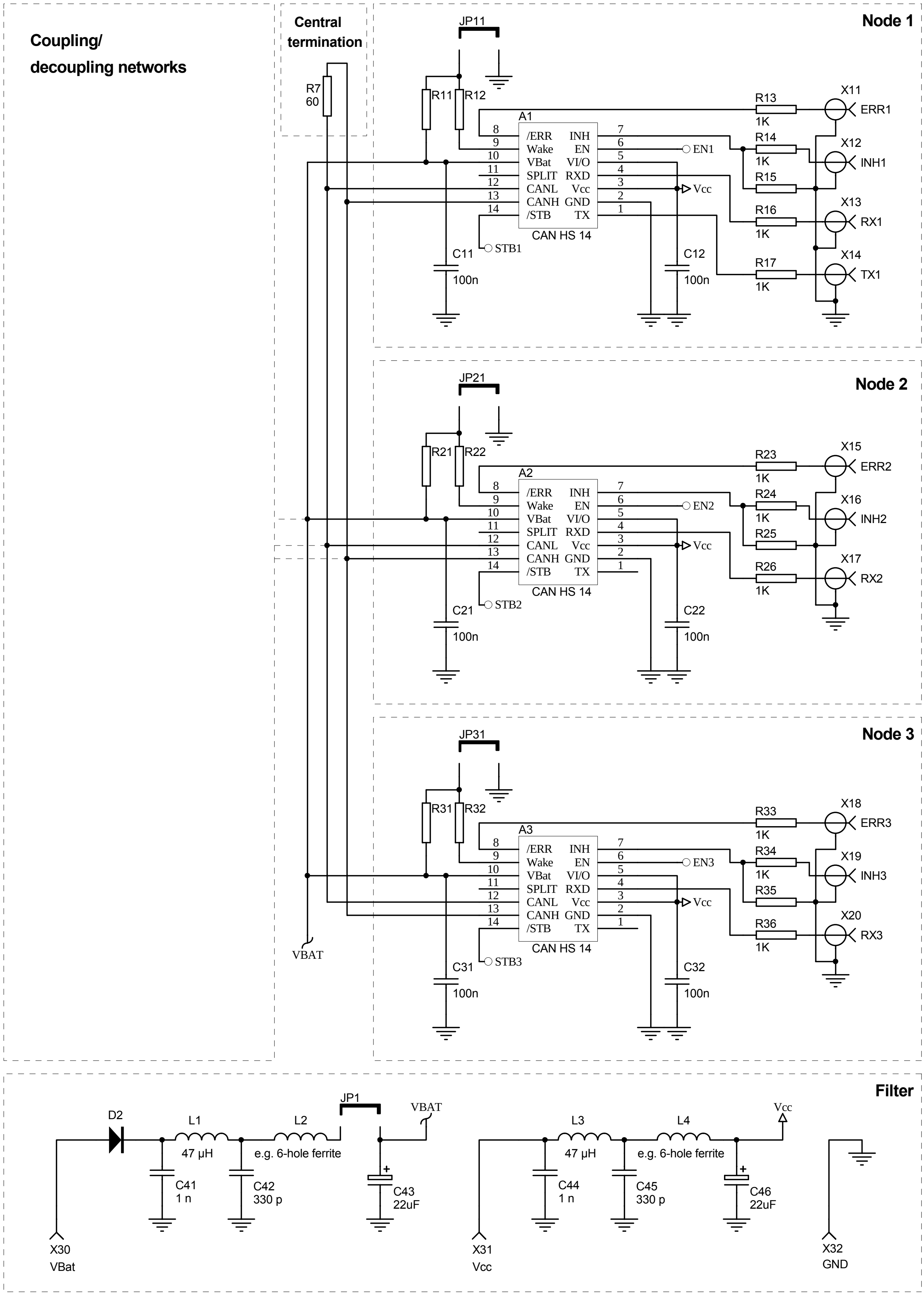

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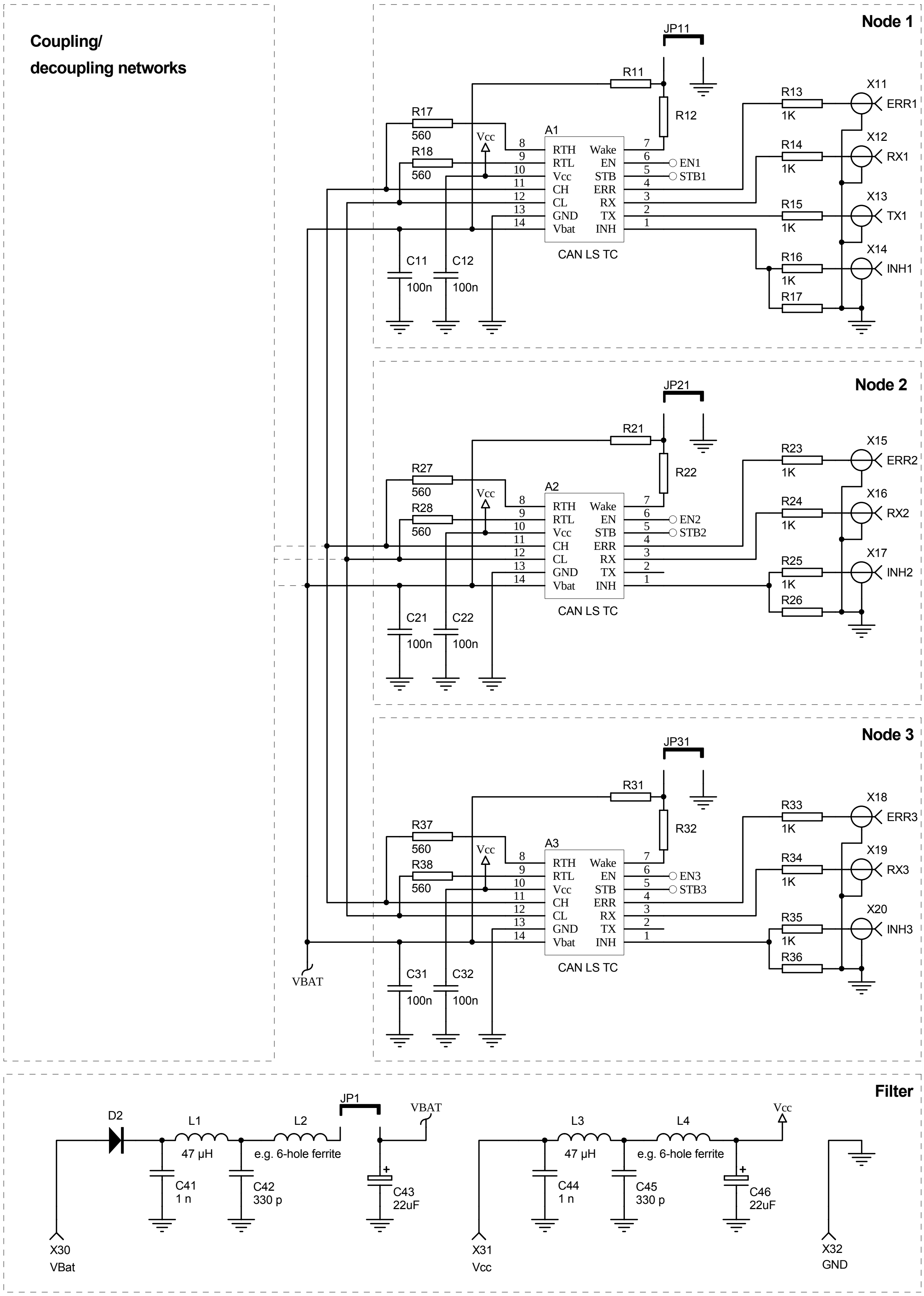
Figure 2 – Example of the circuit diagram of the minimum network for a CAN high speed system for measuring emission and immunity in respect to RF disturbances and transients



IEC 208/07

Figure 3 – Example of the circuit diagram of the minimum network for a CAN low speed system for measuring emission and immunity in respect to RF disturbances and transients

- CAN nodes:

A CAN node consists of a transceiver, mandatory external components for functional settings and support and decoupling networks at monitored pins or inputs. Node 1 operates as a transmitter for a bit pattern, which simulates a CAN message to be received and monitored at the RX output ports of all nodes in the configured network.

At all voltage supply ports (V_{Bat}, V_{CC}) of the transceiver buffer, ceramic capacitors shall be used corresponding to the manufacturers specifications (default value: 100 nF).

Every control input for operation modes shall be connected corresponding to the manufacturers specifications for a setting either to normal, stand by, or sleep mode. Connections to the peripheral control equipment shall be decoupled from the test circuit board.

The resistor values at the wake-up pin (R_{11}, R_{12}, R_{21}, R_{22}, R_{31}, R_{32}) are to be selected corresponding to the manufacturers specifications in the following way:

– resistors R_{11}, R_{21} and R_{31}: maximum specified value (default: 10 kΩ)
– resistors R_{12}, R_{22} and $R_{32:}$ minimum specified value (default: 3,3 kΩ)

For RF decoupling of outputs (RX, ERR, INH) as well as the input TX_1 resistors R = 1 kΩ are used.

In respect to avoid a floating voltage at pin INH (stand by or sleep mode), a pull down resistor shall be used corresponding to the manufacturers specifications (default value R = 10 kΩ).

Before RF and transient testing the wake-up function needs to be tested be using the jumpers JP11, JP21 and JP31.

- Bus termination:

In the test circuit for CAN high speed systems as shown in Figures 1 and 2, the termination shall be realized by a central termination using the resistor R_7 = 60 Ω.

In the test circuit for CAN low speed systems, the termination shall be realized on every CAN node (R = 560 Ω, see Figure 3).

- Filter:

The central voltage supply is buffered by two electrolytic capacitors C_{43} = C_{46} = 22 µF. For the decoupling of external connected voltage supplies V_{CC} and V_{Bat} , two-stage LC-filters are connected to each of them (L_1, C_{41}, L_2, C_{42} at V_{Bat} and L_3, C_{44}, L_4, C_{45} at V_{CC}). The parts L_2 and L_4 should have an impedance above 400 Ω in the frequency range of interest (e.g. 6-hole- ferrites). The jumper JP1 is used to disconnect the supply and RF decoupling filter network for the transient tests at IMP3. In this case, the voltage supply V_{Bat} is directly provided via the IMP3 path.

4.2.1.3 Operation mode definitions

- Definitions of transceiver communication test signals

Two different communication test signals TX1 and TX2 are defined. Depending on partial emission measurement or immunity test, the respective communication test signal (transmitted by transceiver 1) shall be used. Emission measurements in the frequency domain on CAN high speed transceivers shall be done with the communication test signals TX1 and TX2, in the case of CAN low speed system only with communication test signal TX1.

- Communication test signal TX1:

The communication test signal TX1 shall be used for emission measurements and immunity tests with communication (normal mode). The input signal is defined as a square wave with a duty cycle of 50 %. This represents a CAN signal with permanent data alternation (0-1-0 data) with the frequencies and bit rates as shown in Table 3.

Table 3 – Communication test signal TX1

Bus system	f / kHz	Bit rate / kBit/s
High speed	250	500
Low speed	50	100

- Communication test signal TX2:

The communication test signal TX2 shall be used only for emission measurements with CAN high speed systems additionally. The input signal is defined as a square wave with a duty cycle of 90 % with the frequency as shown in Table 4. This represents an asymmetrically data stream.

Table 4 – Communication test signal TX2

Bus system	f / kHz
High speed	50

4.2.1.4 Definition of evaluation criteria for bus system immunity

4.2.1.4.1 Damage test evaluation criteria for bus system immunity

For evaluation of immunity against damages, a functional test of the transceiver shall be performed. The functional test includes:

- send- and receive-functionality,
- error detection,
- wake-up capability by the bus and by the wake-up pin, and
- operation mode setting.

All monitored functions shall be within the specifications given by the semiconductor manufacturer after expose to the disturbances.

4.2.1.4.2 Function test evaluation criteria for bus system immunity

The immunity of a CAN bus system shall be tested in different transceiver modes while the specified function is monitored at pins RX, ERR and INH according to the scheme in Table 5.

Table 5 – Basic scheme for immunity evaluation

Mode	Type of disturbance	Failure validation on pin
Normal	RF / Transients	RX, ERR, INH
Stand by	RF / Transients	RX, INH
Sleep	RF / Transients	INH

The boundary values for normal IC operation at different functional pins defined in Table 6 will be used for failure monitoring.

Table 6 – Boundary values for normal IC operation

Mode	Type of disturbance	TX-signal	Maximum voltage variations V			Maximum time variations µs		
			RX[a,d]	ERR[d]	INH[e]	RX	ERR	INH
Normal	RF	With	± 0,9	± 0,9	± 5	± 0,2 [f] ±1,0 [g]	– [b]	– [b]
	Transient	With	± 0,9	± 0,9	± 5	– [b]	– [b]	– [b]
Standby	RF / Transient	Without	± 0,9	– [c]	± 5	– [b]	– [b]	– [b]
Sleep	RF / Transient	Without	– [c]	– [c]	± 3	– [b]	– [b]	– [b]

[a] The undisturbed voltage level depends on the tested transceiver. For the immunity evaluation, the monitored pin of all transceivers in the network with and without applied disturbances shall be compared by using an oscilloscope. The given values are the maximum allowed variation to the undisturbed signal.

[b] Independent of the duration.

[c] No evaluation, because the output has no function in this mode.

[d] The definition for the maximum deviation of the voltage levels on the RX and/or ERR pin were done according to the transceiver specification.

[e] The definition for the maximum deviation of the voltage levels on the pin INH were done under the following limit conditions: $V_{\text{drop\_typ\_CAN transceiver}}$ = 0,8 V; $V_{\text{on\_typ\_volt.reg.}}$ = 3,6 V; $V_{\text{off\_typ\_volt.reg.}}$ = 0,8 V and possible RF superposition on pin INH with RF influencing of V_{Bat} with an amplitude of approx. 3 V

[f] Only for CAN high speed, 10 % variation of bit time TX1.

[g] Only for CAN low speed, 10 % variation of bit time TX1.

The boundary values for normal IC operation apply to all three transceivers. As soon as at least one transceiver in the network violates a boundary value an error event has occurred. In some cases, a reset of the system may be necessary before the test can be continued.

NOTE To reset an error indicated by the ERR pin, a dominant or recessive level is required for a minimum time at the communication test signal TX1. This minimum reset time is to be chosen according to the semiconductor manufacturer information (typical value > 40 µs).

4.2.2 Emission of RF disturbances

4.2.2.1 Test configuration

4.2.2.1.1 Test circuit diagram

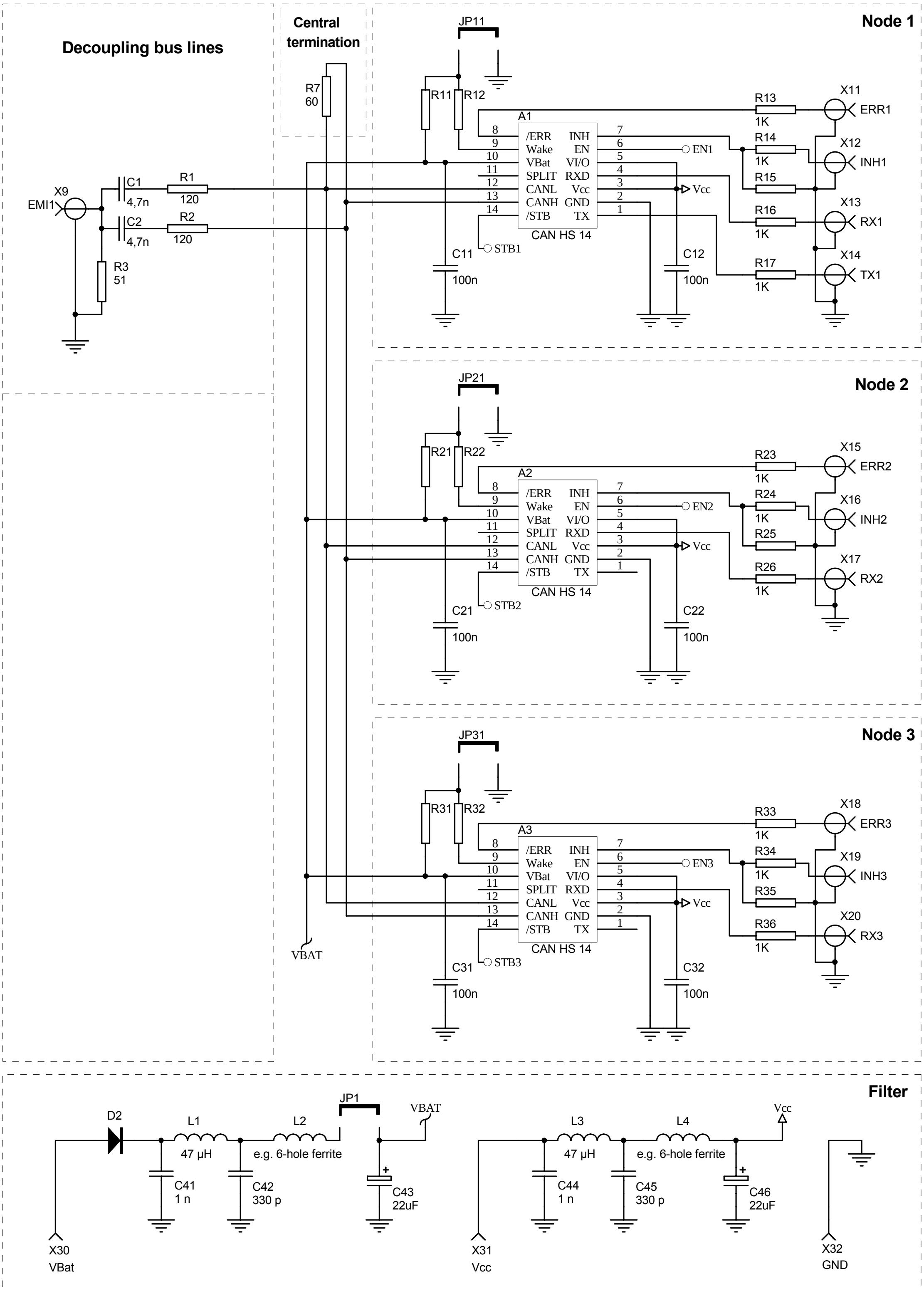


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Figure 4 – Example of the circuit diagram of the minimum network for a CAN high speed system for measuring the emission of RF disturbances

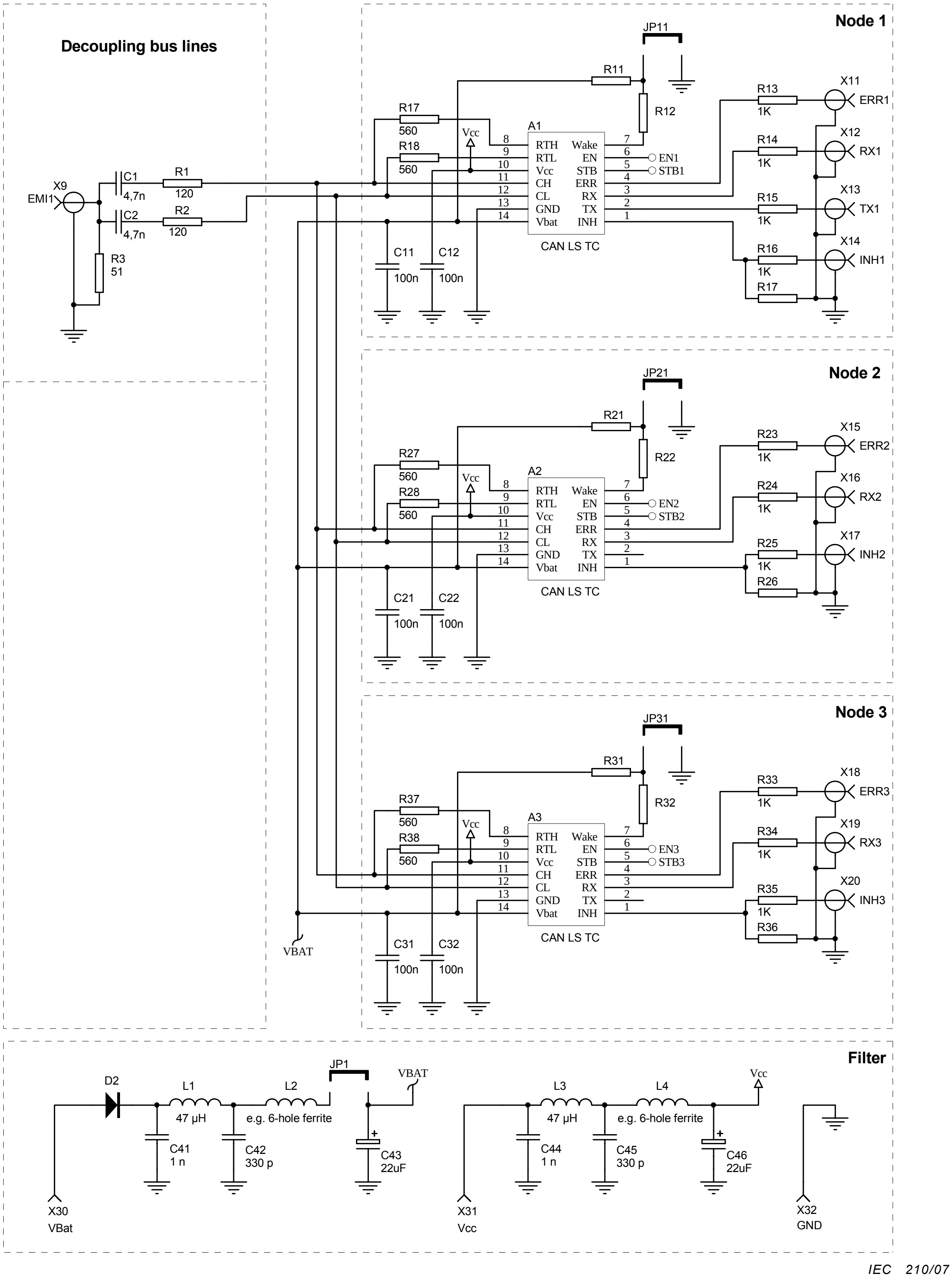

Figure 5 – Example of the circuit diagram of the minimum network for a CAN low speed system for measuring the emission of RF disturbances

4.2.2.1.2 Networks for decoupling of disturbances

The decoupling of disturbances shall be realized by impedance matching networks according to IEC 61967-4 with passive components (see Figures 4 and 5). The maximum components mismatch is 1 %, which can be confirmed by measurement. For the resistors R_1 and R_2 used for symmetrical decoupling, a maximum mismatch of 0,1 % is recommend (see Table 7).

Table 7 – Overview of decoupling ports for emission

Port	Purpose	Components
EMI1	RF decoupling on bus lines	In pairs RC-serial circuit, matching resistor: $R_1 = R_2 = 120\ \Omega$, $C_1 = C_2 = 4{,}7$ nF, $R_3 = 51\ \Omega$

- Decoupling port EMI1

The capacitors C = 4,7 nF realize the DC-decoupling of bus lines from the connected measurement equipment. The decoupling resistors R = 120 Ω build a power combiner for symmetrical decoupling of RF disturbances. The resistor R = 51 Ω builds the voltage divider according to IEC 61967-4.

4.2.2.2 Test set-up

The RF emission measurement of transceiver shall be carried out according to Figure 6 on the bus lines in the frequency and the time domain.

All networks for transient and RF immunity tests shall be disconnected from the test circuit during the emission measurements.

- Measurements in the frequency domain

To evaluate the emission of the transceiver (common mode emission of the differential mode data transfer) in frequency domain, the spectrum of the bus signals CAN_High and CAN_Low as sum according to IEC 61967-4 should be measured.

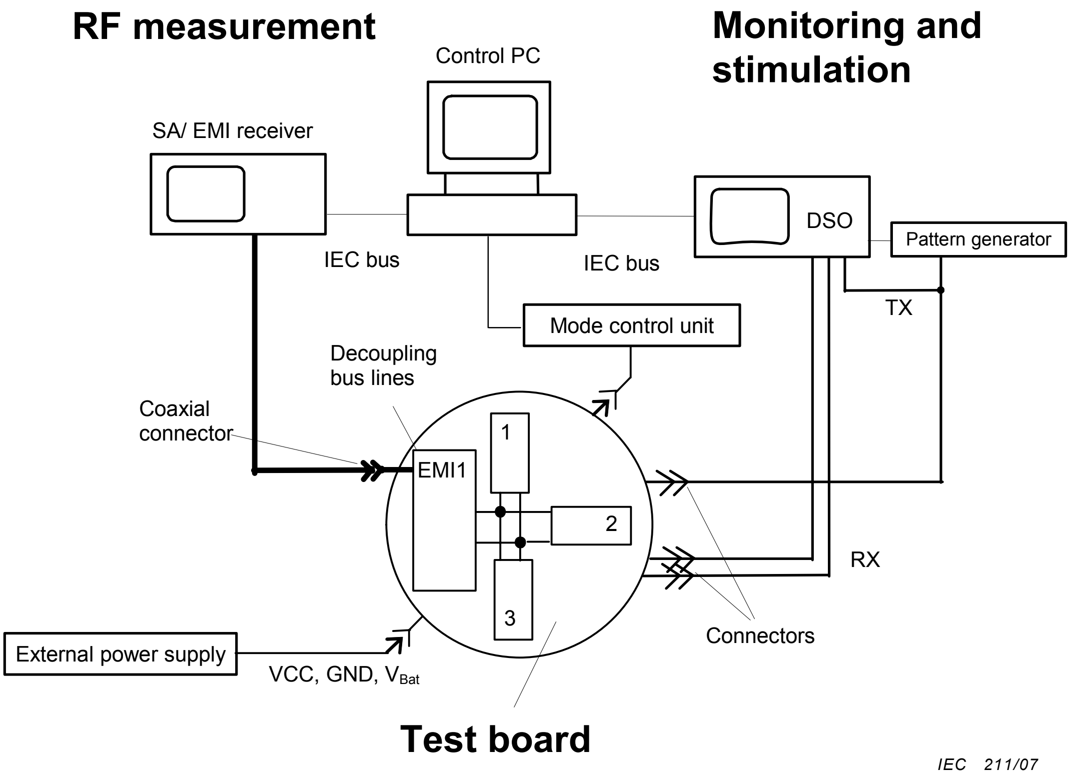

Figure 6 – Test set-up for measurement of RF disturbances on the bus lines

Test equipment requirements:

– Spectrum analyzer (SA)/ EMI receiver	according to CISPR 16
– Digital storage oscilloscope (DSO) with probes (≥ 1 MΩ)	bandwidth ≥ 500 MHz
– Test board	according to Annex A
– Pattern generator	
– External power supply	
– Mode control unit	(if possible remotely controlled by the PC)
– PC	

The input of the measuring instrument shall be connected with the port EMI1 of the test board by a short coaxial cable according to Figure 7.

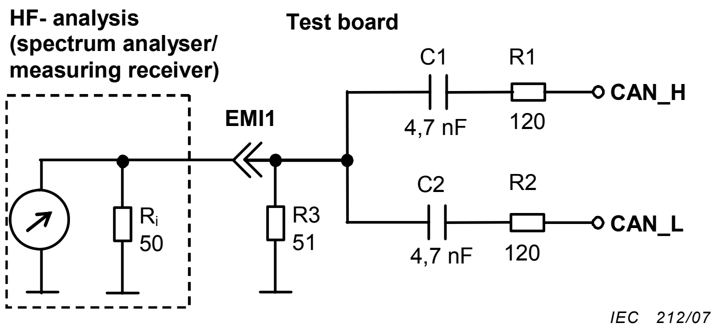

Figure 7 – Decoupling network for emission measurement at CAN_High and CAN_Low in the frequency domain

• Measurements in the time domain

To evaluate the emission of the transceiver in time domain, a measurement of the bus signals CAN_High and CAN_Low and its mathematical addition should be done by using of a digital storage oscilloscope.

To determine the emission of the bus lines in the time domain, the signals CAN_High and CAN_Low shall be measured directly on the test board with high impedance probes during communication with communication test signal TX1. The measuring instrument or software should be used to build the mathematical addition of the signals.

• Characterization of the measurement port/path

The insertion losses (S_{21} measurement) between the respective transceiver signal pads to the port EMI1 of the test board (without transceiver) shall be measured and documented in the test report.

Each decoupling path shall be measured separately. By this way, the other pads should be unconnected.

4.2.2.3 Test procedure and parameters

The characterization of the RF emission on the bus lines shall be performed with the following test parameters (Table 8) and documented in a diagram in the test report.

Measurements in frequency domain

Table 8 – Parameters for emission test in the frequency domain

Bus system	$\frac{f}{\text{kHz}}$	Mode	Test signal
High speed	0,15 to 1 000	Normal/high speed [a]	TX1, TX2
Low speed	0,15 to 1 000	Normal	TX1

[a] In case of adjustable slope for the bus signals, the maximum slew rate shall be used in the test.

The settings of the RF analyzer or EMI receivers are given in Table 9.

Table 9 – Settings of the measurement device for measurement of emission in the frequency domain

Measuring equipment	Spectrum analyzer	EMI receiver
Detector	Peak	
Frequency range	0,15 to 1 000 MHz	
Resolution bandwidth (RBW) 150 kHz to 30 MHz 30 MHz to 500 MHz	 10 kHz 100 kHz	 9 kHz 120 kHz
Video bandwidth (VBW)	equal to RBW	-
Numbers of sweeps	10 (max hold)	-
Measurement time per step	-	≥ 1 ms
Frequency sweep time	≥ 20 s	-
Frequency step width 150 kHz to 30 MHz 30 MHz to 500 MHz	 - -	 ≤ 9 kHz ≤ 120 kHz

<u>Measurements in time domain</u>

The emission in the time domain shall be measured with test signal TX1 and documented in the test report. The bus signals shall be measured directly on the test board at the pins CAN_High and CAN_Low of transceiver node 1 with high-impedance probes.

4.2.3 Immunity to RF disturbances

4.2.3.1 Test configuration

4.2.3.1.1 Test circuit diagram

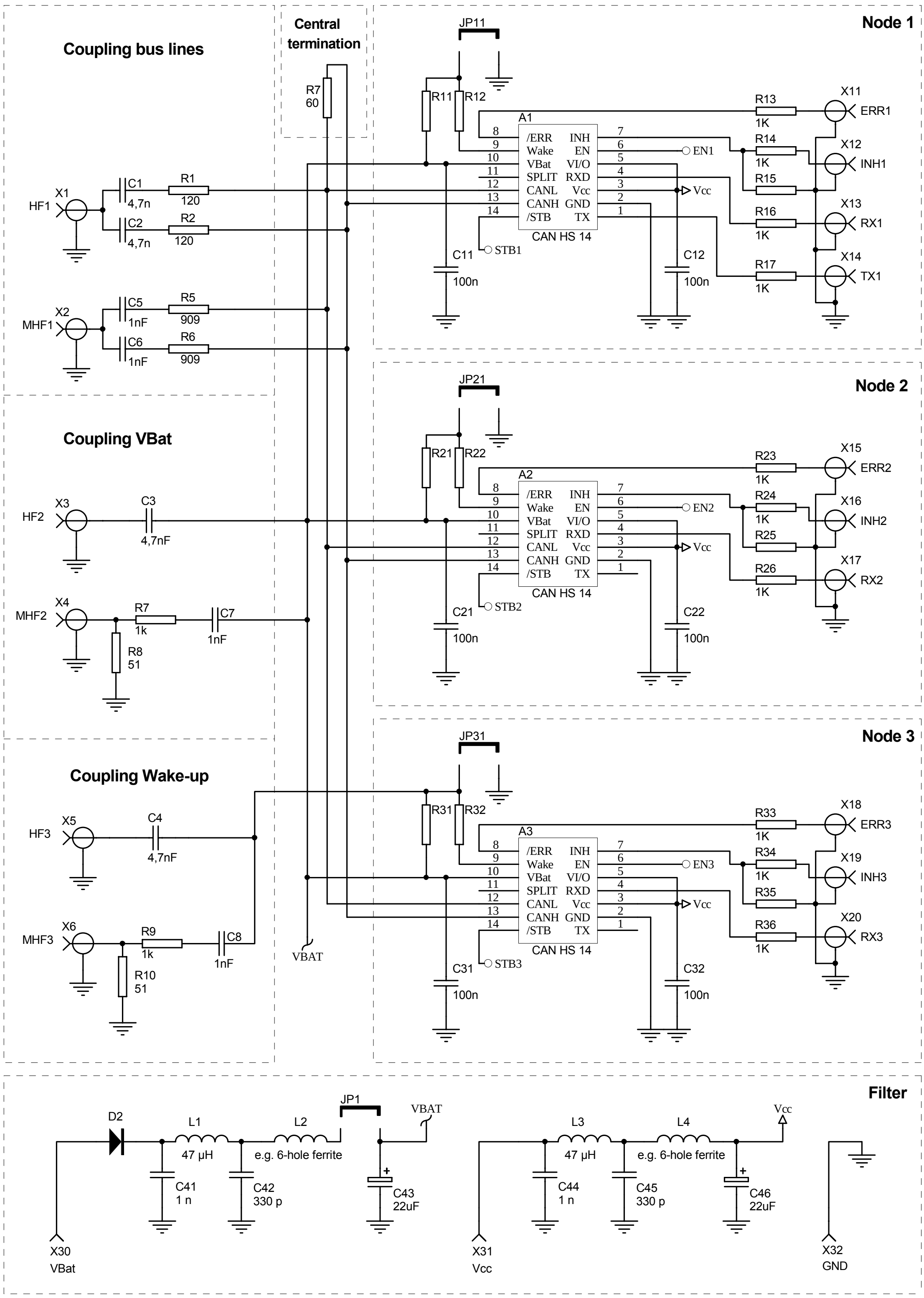

Figure 8 – Example of the circuit diagram of the minimum network for a CAN high speed system for testing the RF immunity

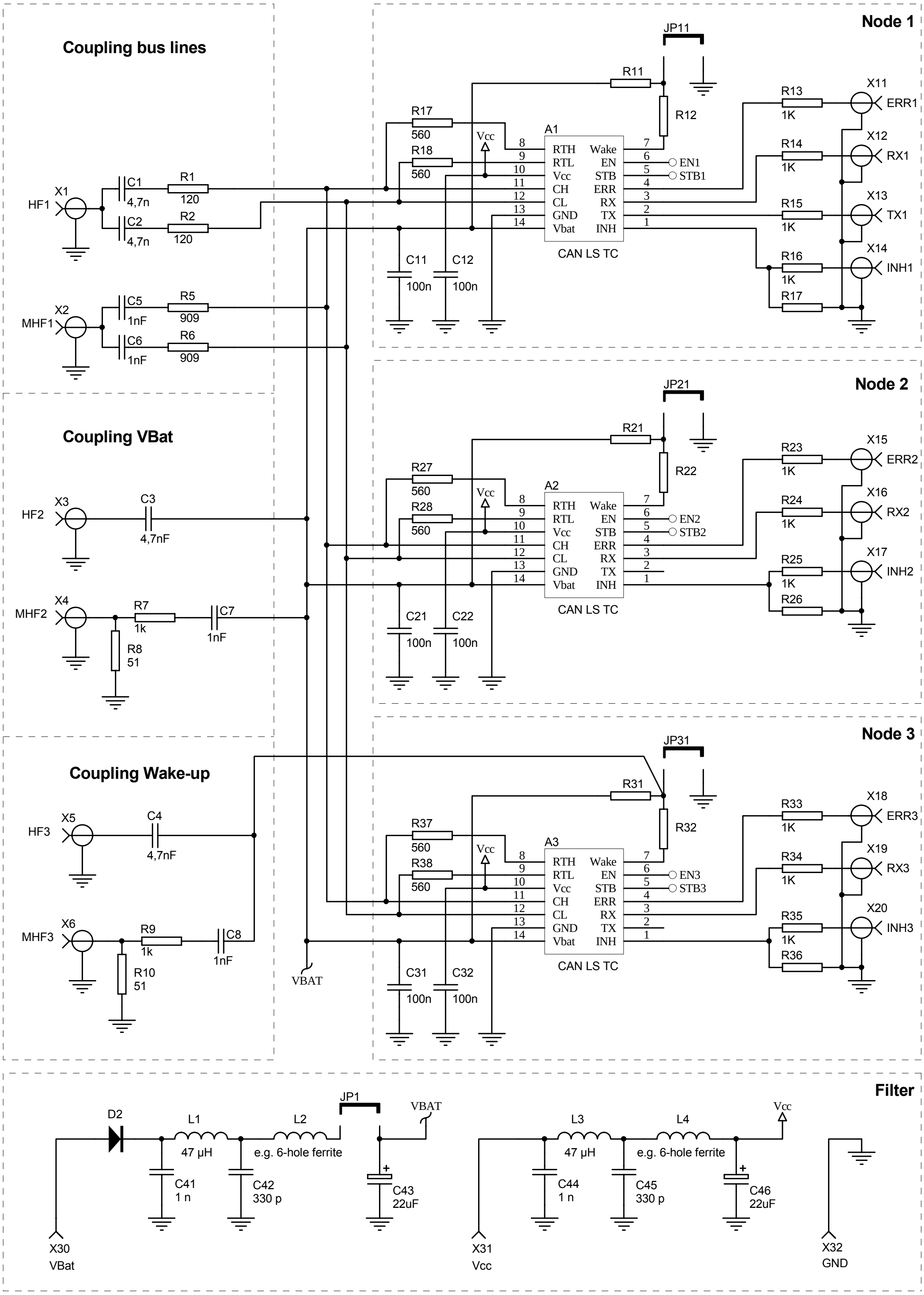

Figure 9 – Example of the circuit diagram of the minimum network for a CAN low speed system for testing the RF immunity

4.2.3.1.2 Networks for coupling and decoupling of disturbances

The coupling of disturbances shall be realized by passive components (see Figures 8, 9 and Table 10). The maximum components mismatch is 1 %, which can be confirmed by measurement. For the resistors R_1 and R_2 used for symmetrical coupling, a maximum mismatch of 0,1 % is recommend.

Table 10 – Overview of coupling ports

Port	Purpose	Components
RF injection		
HF1	Symmetrical RF coupling on CAN ports	In pairs RC-serial circuit: R_1 = R_2 = 120 Ω, C_1 = C_2 = 4,7 nF
HF2	RF-coupling on V_{Bat}	C_3 = 4,7 nF
HF3	RF-coupling on wake-up	C_4 = 4,7 nF
RF monitoring		
MHF1	Symmetrical RF decoupling on CAN ports for additional measurement of RF disturbances during immunity tests	In pairs RC-serial circuit: R_5 = R_6 = 909 Ω, C_5 = C_6 = 1 nF
MHF2	RF decoupling on V_{Bat} for additional measurement of RF disturbances during immunity tests	Voltage divider and DC-block: R_7 = 1 kΩ, R_8 = 50 Ω, C_8 = 1 nF
MHF3	RF decoupling on wake-up for additional measurement of RF disturbances during immunity tests	Voltage divider and DC-block: R_9 = 1 kΩ, R_{10} = 50 Ω, C_8 = 1 nF

- Coupling ports HF1 to HF3

The coupling capacitors (C = 4,7 nF) realize the DC-decoupling of the tested port to the connected test or measurement equipment. In case of bus lines, the coupling resistors (R = 120 Ω) built a power splitter for symmetrical coupling of RF disturbances.

4.2.3.2 Test set-up

4.2.3.2.1 General

The measurement of the RF immunity of the CAN transceiver shall be carried out by direct power injection (DPI) according to IEC 62132-1 and IEC 62132-4. This method is complementary to the emission measurement method according to IEC 61967-4 and the same test boards can be used. In addition, the applied RF voltages onto the respective transceiver pin may be measured at the output port MHF1 to MHF3.

All networks for transient coupling and emission measurement shall be disconnected from the test circuit. For test level definition, the forward RF power shall be used. Only the RF injection port necessary for the test shall be connected. A general test set-up is illustrated in Figure 10.

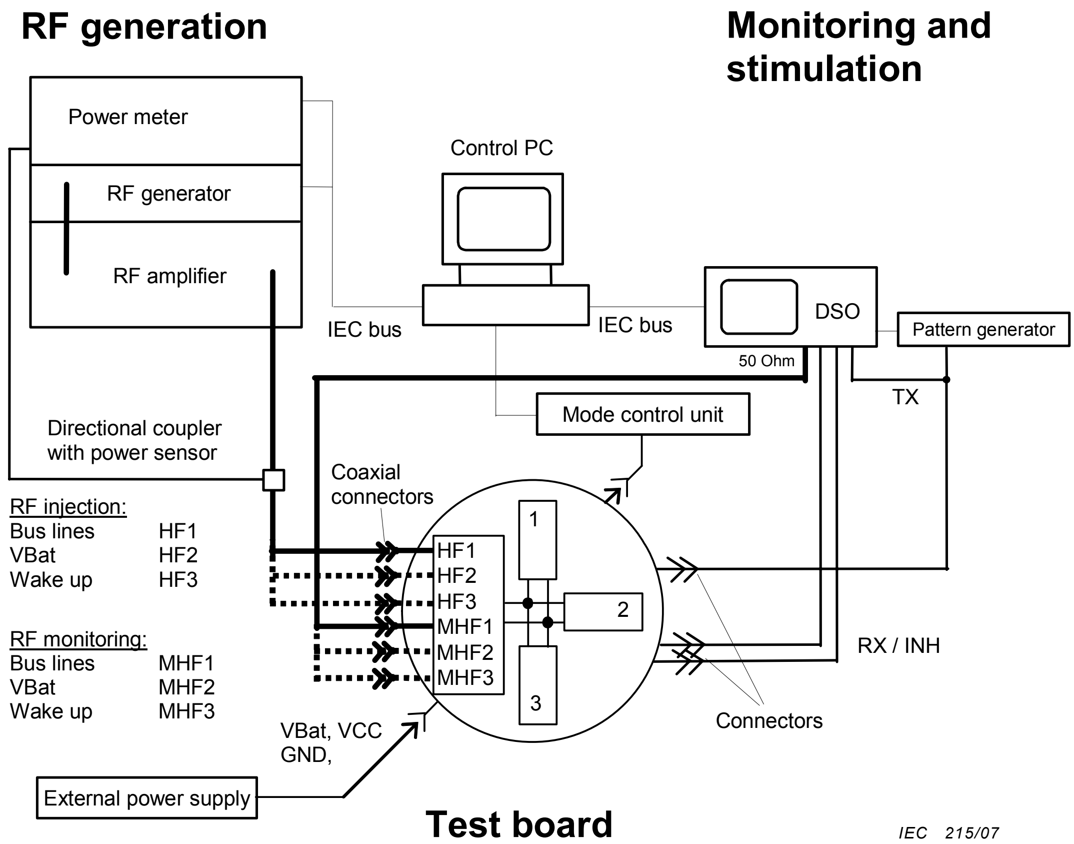

Figure 10 – Test set-up for DPI measurements

Test equipment requirements:

• RF generator	f = 1 – 1 000 MHz, AM
• RF amplifier	$P_{CW} \geq 5$ W
• Power meter with directional coupler	f = 1 – 1 000 MHz
• Test board	according to Clause A.1
• Oscilloscope	bandwidth ≥ 1 000 MHz
• Pattern generator	
• External power supply	
• Mode control unit	(if possible remotely controlled by the PC)
• PC	

4.2.3.2.2 Coupling and decoupling networks at bus lines

The RF disturbances coupling network consists of capacitors C_1 and C_2 and resistors R_1 and R_2 in accordance with Figure 11. The wideband power amplifier output shall be connected with port HF1 of the test board by a short coaxial cable (0,5 m) via a transition power sensor head (or a directional coupler with separate power sensors). The transition head shall be located as close as possible to the test board.

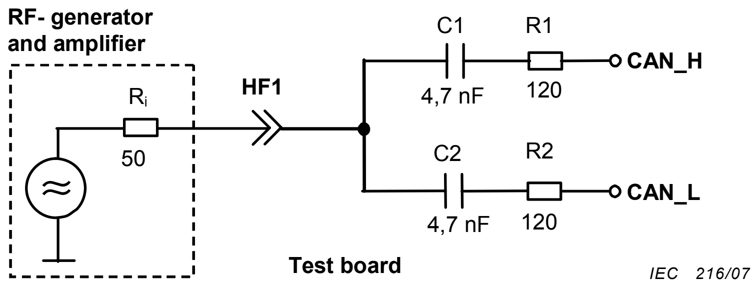

Figure 11 – Coupling network for DPI measurements on bus lines

The RF disturbance monitoring network for the bus lines consists of capacitors C_5 and C_6 and resistors R_5 and R_6 in accordance with Figure 12.

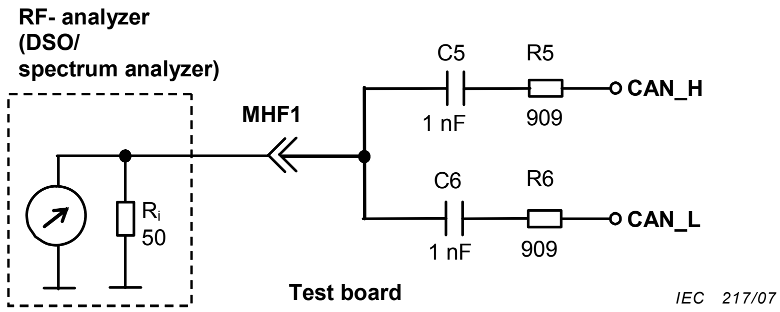

Figure 12 – RF monitoring network for DPI measurements of bus lines

The voltage at the input impedance of a 50 Ω measuring instrument ($V_{\text{Instrument}}$) has a ratio to the common mode voltage of the bus lines, defined by the RF monitoring network, according to the following equation:

$$V_{\text{Instrument}} = 0{,}1 \frac{V_{\text{CAN\_H}} + V_{\text{CAN\_L}}}{2}$$

The output MHF1 shall be connected with a digital storage oscilloscope (50 Ω) or spectrum analyzer.

4.2.3.2.3 Coupling and decoupling networks at V_{Bat} line

The RF disturbances coupling network consists of capacitor C_3 according to Figure 13. The wideband power amplifier output shall be connected with port HF2 of the test board by a short coaxial cable (0,5 m) via a transition power sensor head (or a directional coupler with separate power sensors). The transition head shall be located as close as possible to the test board.

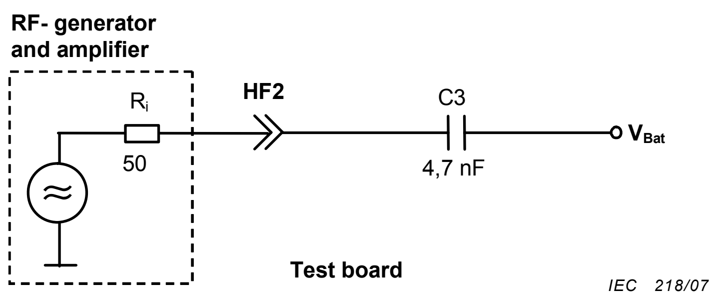

Figure 13 – Coupling network for DPI measurements on V_{Bat}

The RF disturbance monitoring network for the V_{Bat} line consists of capacitor C_7 and resistors R_7 and R_8 in accordance with Figure 14.

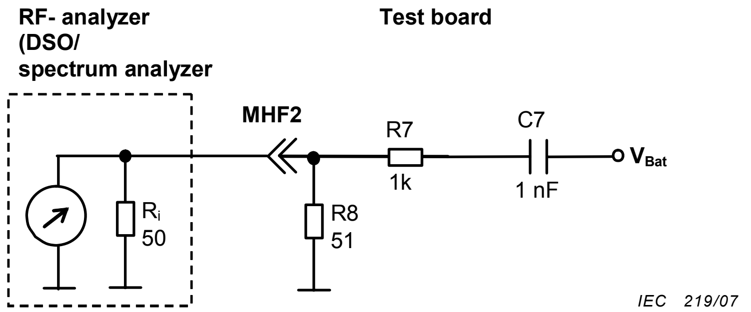

Figure 14 – RF monitoring network for DPI measurements of V_{Bat}

The voltage at the input impedance of a 50 Ω measuring instrument ($V_{\mathrm{Instrument}}$) has a ratio to the battery voltage (V_{Bat}), defined by the RF monitoring network, according to the following equation:

$$V_{\mathrm{Instrument}} = 0{,}025\ V_{\mathrm{Bat}}$$

The output MHF2 shall be connected with a digital storage oscilloscope (50 Ω) or spectrum analyzer.

4.2.3.2.4 Coupling and decoupling networks at wake-up

The RF disturbances coupling network consists of capacitor C_4 according to Figure 15. The wideband power amplifier output shall be connected with port HF3 of the test board by a short coaxial cable (0,5 m) via a transition power sensor head (or a directional coupler with separate power sensors). The transition head shall be located as close as possible to the test board.

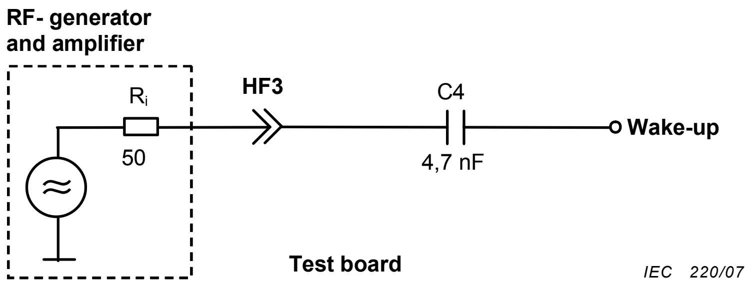

Figure 15 – Coupling network for DPI measurements on wake-up

The RF disturbance monitoring network for the wake-up line consists of capacitor C_8 and resistors R_9 and R_{10} in accordance with Figure 16.

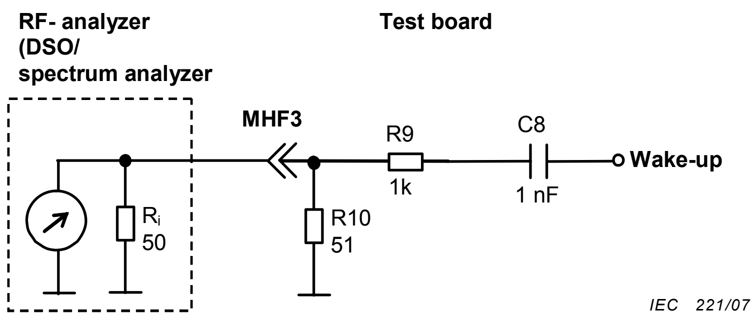

Figure 16 – RF monitoring network for DPI measurements of wake-up

The voltage at the input impedance of a 50 Ω measuring instrument ($V_{\text{Instrument}}$) has a ratio to the wake-up voltage ($V_{\text{Wake-up}}$), defined by the RF monitoring network, according to the following equation:

$$V_{\text{Instrument}} = 0{,}025\ V_{\text{Wake-up}}$$

The output MHF3 shall be connected with a digital storage oscilloscope (50 Ω) or spectrum analyzer.

- Characterization of the measurement port/ path

The insertion losses (S_{21} measurement) of the ports RF1 to RF3 to the respective transceiver signal pad of the test board (without transceiver) shall be measured and documented in the test report.

For all measurements to characterize the power injection set-up, all components which are directly connected to the coupling path (e.g. filter to power supply or loads) shall be placed on the PCB. For characterization of coupling path for multiple pin power injection, each coupling path shall be measured separately. By this way the other pads should be unconnected.

4.2.3.3 Test procedure and parameters

To determine the immunity of the transceiver against narrow-band disturbances (defined in IEC 62132-1) measurements with the following test values shall be carried out (see Table 11):

Table 11 – Specifications for DPI measurements

$\frac{f}{\text{MHz}}$	Parameters	
	Range	Step
	1 to 10	0,25
	10 to 100	1
	100 to 200	2
	200 to 400	4
	400 to 1 000	10
Minimum forward power	10 dBm (10 mW)	
Maximum forward power	36 dBm (4 W)	
Power step size	0,5 dB	
Power control procedure	Searching for malfunction while power is stepwise increased. A combined control procedure to reduce the measurement time can be used. As a result, the immunity threshold curve with forward power as the parameter shall be documented. Example: Procedure for each frequency: • start with maximum forward power or with the level that caused a malfunction at the last frequency, • in case of malfunction at this test power test with half power, • increase the power by power step size until malfunction occurs or maximum forward power. • the immunity level for this frequency is the maximum forward power that acts no malfunction	
Dwell time	1 s	
Modulation	CW, AM 80 %, 1 kHz [a]	

[a] Use peak conversion for the forward power ($\hat{P}_{\text{AM}} = \hat{P}_{\text{CW}}$)

The test shall be performed and documented for symmetric coupling according to the scheme in Table 12. Tests using unsymmetrical coupling according to the scheme below may be added for information purposes.

Table 12 – Required DPI measurements for function test

Mode	Coupling				Failure validation on pin		
	Port	Pin	Test signal	Parameter	RX	ERR	INH
Normal	HF1	CAN_H, CAN_L	TX1	Symmetric	**X**	**X**	**X**
				5 % unsymmetrical [a]	X	X	X
				10 % unsymmetrical [a]	X	X	X
	HF2	V_{Bat}	TX1	-	**X**	**X**	**X**
	HF3	Wake-up	TX1	-	**X**	**X**	**X**
Stand by	HF1	CAN_H, CAN_L	-	Symmetric	**X**		**X**
				5 % unsymmetrical [a]	X		X
				10 % unsymmetrical [a]	X		X
	HF2	V_{Bat}	-	-	**X**		**X**
	HF3	Wake-up	-	-	**X**		**X**
Sleep	HF1	CAN_H, CAN_L	-	Symmetric			**X**
				5 % unsymmetrical [a]			X
				10 % unsymmetrical [a]			X
	HF2	V_{Bat}	-	-			**X**
	HF3	Wake-up		-			**X**

[a] To adjust the imbalance of coupling the resistance values of the two coupling resistors, R_1 and R_2 shall be changed according to Table 13. Tests are optional and should be done only with CW disturbances.

Table 13 – Combination of resistors for coupling on DPI measurements

	R_1 / Ω	R_2 / Ω
Symmetry	120	120
5 % Unbalance	126	114
10 % Unbalance	132	108

For each measurement, an immunity threshold curve with the forward power as the parameter has to be determined and presented in the test report in a diagram. The monitored RF coupling voltage on the corresponding pin should be added additionally.

4.2.4 Immunity to transients

4.2.4.1 Test configuration

4.2.4.1.1 Test circuit diagram

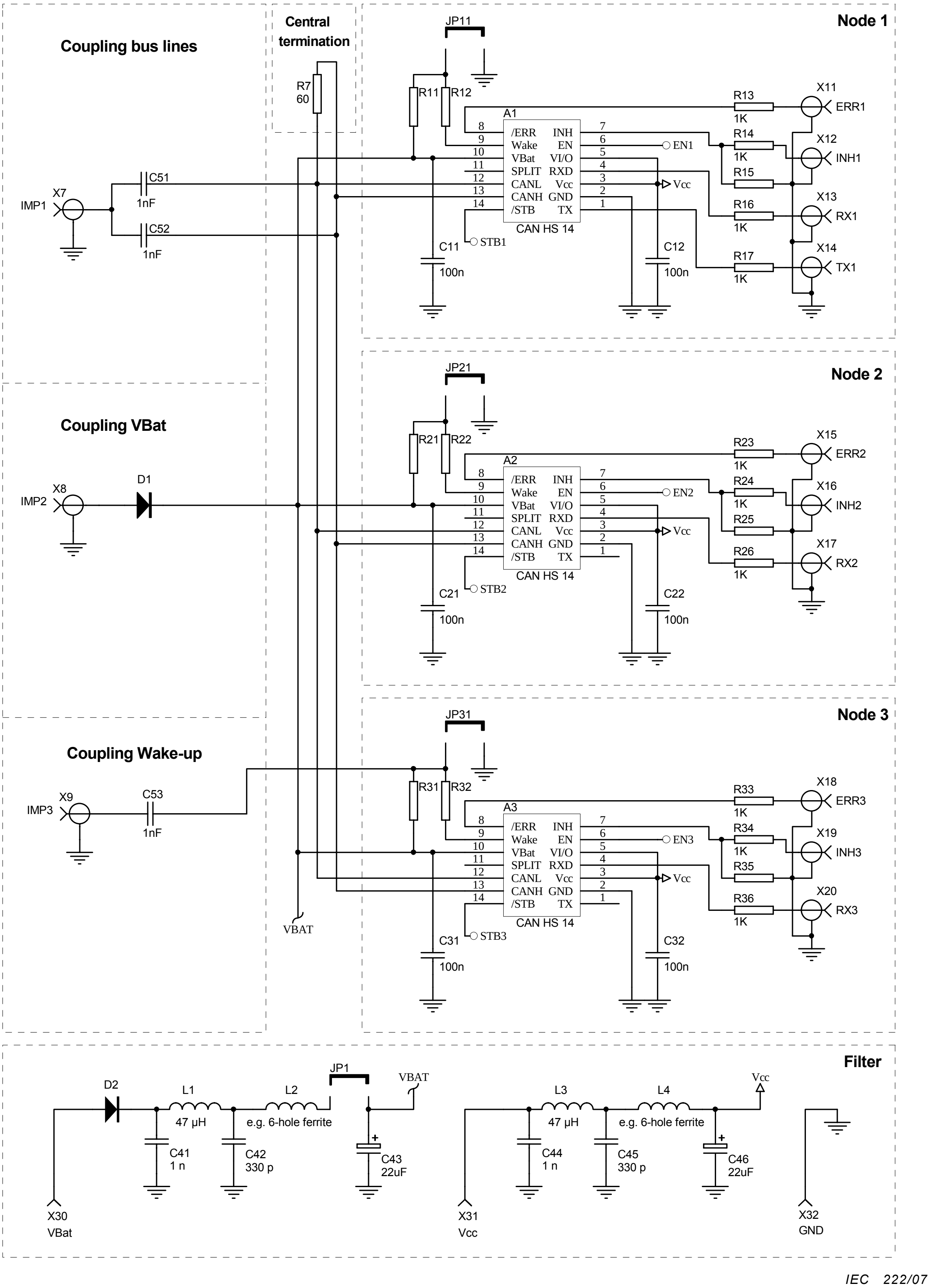

Figure 17 – Example of the circuit diagram of the minimum network for a CAN high speed system for testing the transient immunity

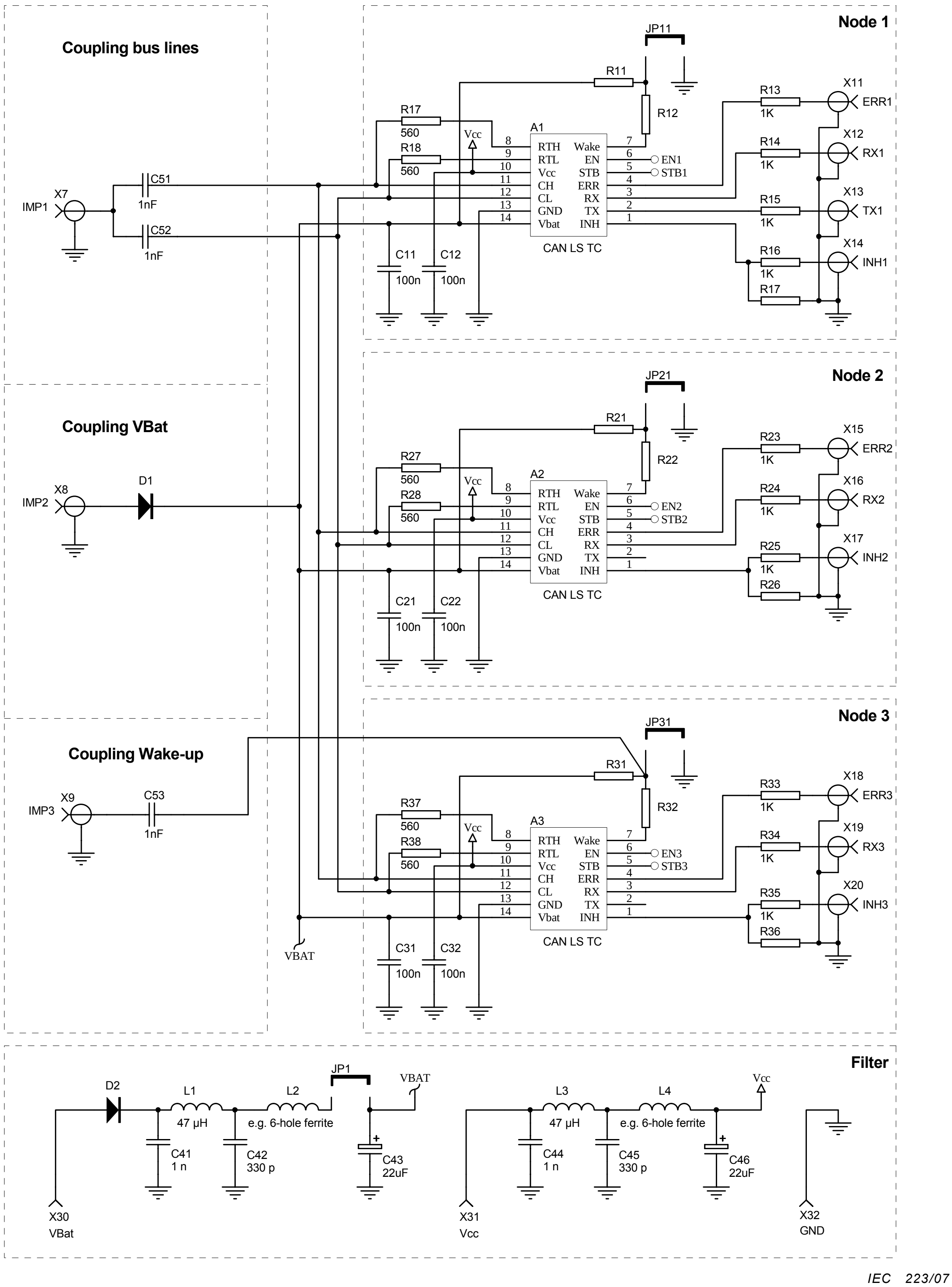

Figure 18 – Example of the circuit diagram of the minimum network for a CAN low speed system for testing the transient immunity

4.2.4.1.2 Coupling and decoupling of disturbances

The coupling of disturbances shall be realized by passive components (see Figures 17, 18 and Table 14). The maximum components mismatch is 1 %, which can be confirmed by measurement.

Table 14 – Overview of coupling ports

Port	Purpose	Components
IMP1	Symmetrical transient coupling on CAN ports	In pairs $C_{51} = C_{52}$ = 1 nF
IMP2	Transient coupling on V_{Bat}	Diode D1 (repetitive peak reverse voltage V_{RRM} > 200 V, non-repetitive peak forward current I_{FSM} > 10 A)
IMP3	Transient coupling on wake-up	C_{53} = 1 nF

- Coupling ports IMP1 and IMP3

The coupling capacitors (C = 1 nF) represent the capacitive disturbance coupling of the supply line to the corresponding line with 100 pF/m and a coupling length of 10 m.

- Coupling port IMP2

Transients at voltage supply line V_{Bat} shall be coupled directly via a reverse protection diode D1. Such a diode is a mandatory passive component on every electronic control unit.

4.2.4.2 Test set-up

4.2.4.2.1 General

For testing the immunity against transients on the bus, power supply line, as well as on the wake-up line, a test set-up according to Figure 19 shall be used. The coupling network for bus and wake-up line is similar to the DPI network (IEC 62132-4), supply line coupling and test pulses are according to ISO 7637-2.

NOTE A dedicated version of a transient test method is under development by the IEC and will be integrated during the next maintenance cycle.

All networks for RF coupling tests and emission measurement shall be disconnected from the test circuit. Only the pulse injection port necessary for the test shall be connected.

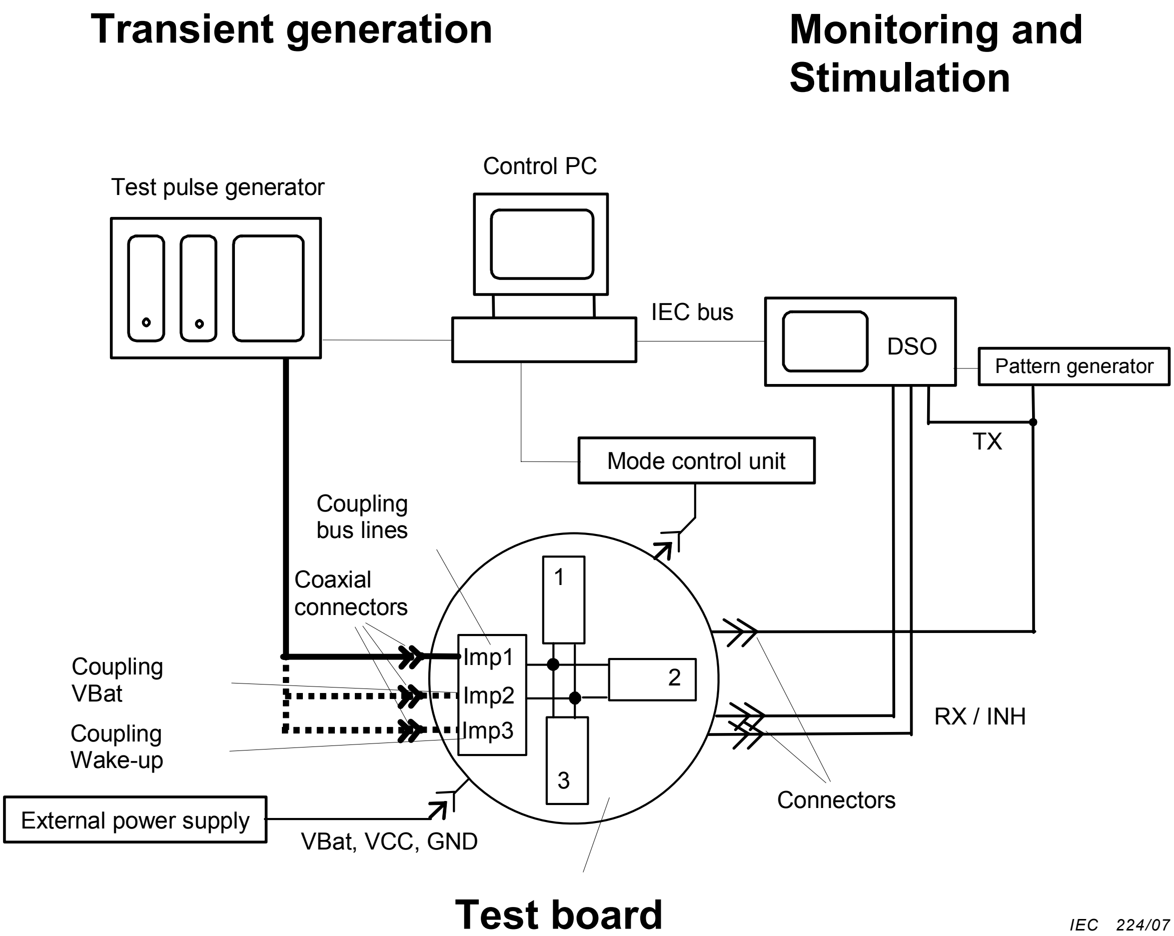

Figure 19 – Test set-up for direct capacitive impulse coupling

Test equipment requirements:

- Test pulse generator according to ISO 7637- 2
- Test board according to Clause A.1
- Oscilloscope bandwidth ≥ 500 MHz
- Pattern generator
- External power supply
- Mode control unit (if possible remotely controlled by the PC)
- PC

4.2.4.2.2 Coupling network at bus lines

The transient coupling network consists of capacitors C_{51} and C_{52} as shown in Figure 20. The test pulse generator shall be connected with the port IMP1 of the test board by a short coaxial cable (0,5 m). The transients are coupled through two lumped capacitors to the bus lines according to Figure 20.

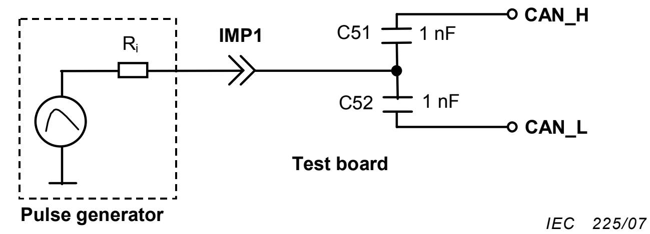

Figure 20 – Coupling network for direct capacitive impulse coupling on CAN_High and CAN_Low

4.2.4.2.3 Coupling network at V_{Bat} line

The transient coupling network consists of diode D1 as shown in Figure 21. This diode shall be able to withstand a test voltage of 200 V and handle a forward peak current of minimum 10 A. The test pulse generator shall be connected with the port IMP2 of the test board by a short coaxial cable (0,5 m). The voltage supply (V_{Bat}) is provided by the pulse generator. The filter network shall be disconnected from the central power line supply V_{Bat} by opening the jumper JP1 in order to avoid a reaction of the filter network to the coupled voltage on the pin of the transceiver. The coupling path for the V_{Bat} line is shown in Figure 21.

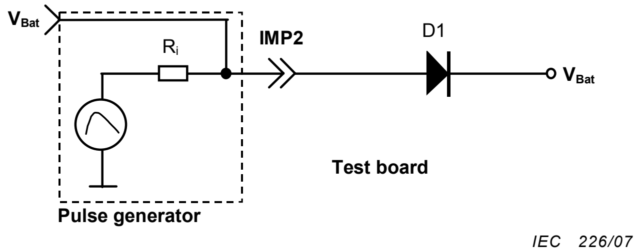

Figure 21 – Coupling network for direct capacitive impulse coupling on V_{Bat}

4.2.4.2.4 Coupling network at wake-up

The transient coupling network consists of capacitor C_{53} as shown in Figure 22. The test pulse generator shall be connected with the port IMP3 of the test board by a short coaxial cable (0,5 m). By this way the transients are coupled through a lumped capacitor according to Figure 22 to the wake-up line of the transceiver 2 in the minimal test network.

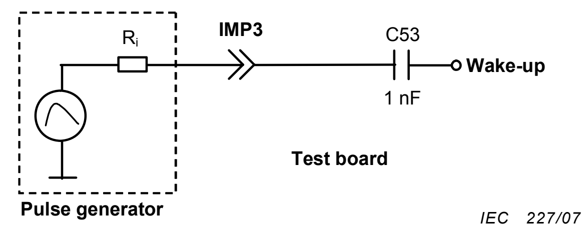

Figure 22 – Coupling network for direct capacitive impulse coupling on wake-up

- Characterization of the measurement port/ path

The test pulses transmitted from the ports IMP1, IMP2 and IMP3 to the respective pad of the transceiver shall be measured on the test board at the landing pad of the pin under test (without transceiver) and documented in the test report.

4.2.4.3 Test procedure and parameters

4.2.4.3.1 Functional test

- Test parameter

The transceiver immunity against transients (defined in ISO 7637-2) shall be tested with the following parameters:

Table 15 – Parameters for functional test

Test pulse [1]	U_{smax} / V	Pulse/ burst repetition frequency ($1/t_1$[a]) Hz	Test duration min	R_i / Ω	Remarks
1[b]	− 200	2	1	10	t_2 = 0 s [c]
2a	+ 100	2	1	2	
3a	− 300	10	1	50	
3b	+ 200	10	1	50	

[a] According to ISO 7637-2

[b] Parameters for rise time and duration for 12 V- systems

[c] Battery off time

- Test procedure

The amplitudes of the transients shall be increased until malfunction function occurs or the peak level has been reached. The step size shall be 10 V. For every voltage level, a dwell time of 5 s is required. The maximum voltage level for the immunity achieved in this case shall be proved with a dwell time of 1 min. As a test result, the respective peak voltage values of each standard pulse (see Table 15) shall be documented for the immunity of the bus system in accordance with 4.2.1.4. The maximum test values are given in Table 15.

The measurements for functional test are to be carried out and documented for operation mode and monitoring signal as specified in Table 16.

Table 16 – Required impulse tests for functioning

Mode	Coupling		TX signal	Failure validation on pin		
	Port	Pin		RX	ERR	INH
Normal	IMP1	CAN_H, CAN_L	TX1	X	X	X
	IMP2	V_{Bat}	TX1	X	X	X
	IMP3	Wake-up	TX1	X	X	X
Stand by	IMP1	CAN_H, CAN_L	-	X		X
	IMP2	V_{Bat}	-	X		X
	IMP3	Wake-up	-	X		X
Sleep	IMP1	CAN_H, CAN_L	-			X
	IMP2	V_{Bat}	-			X
	IMP3	Wake-up	-			X

4.2.4.3.2 Damage test

- Test parameter

In addition to functional testing damage tests with the test parameters specified in Table 17 shall be performed:

Table 17 – Parameters for impulse test (damage test)

Test pulse[a]	U_s / V	Pulse/ burst repetition frequency ($1/t_1$[a]) Hz	Test duration min	R_i / Ω	Remarks
1[b]	− 100	2	1	10	t_2 = 0 s [c]
2a	+ 50	2	1	2	
3a	− 150	10	1	50	
3b	+ 100	10	1	50	

[a] According to ISO 7637-2

[b] Parameters for 12 V- systems

[c] Battery off time

- Test procedure

The measurements for damage test are to be carried out and documented according to Table 18 – only for normal mode with IMP1, IMP2 and IMP3.

Table 18 – Required impulse tests for damage

Mode	Coupling		Test signal	Failure validation
	Port	Pin		
Normal	IMP1	CAN_H, CAN_L	TX1	After each single test
	IMP2	V_{Bat}	TX1	
	IMP3	Wake-up	TX1	

The performance of the device (IC) has to be evaluated again after each single test (coupling on IMP1, IMP2 and IMP3) by a complete functional test as described in 4.2.1.4 and a leakage current measurement of the tested pin to ground prior and after the test.

4.3 ESD

4.3.1 Test conditions

The requirements of IEC 61000-4-2 climatic environmental conditions shall be applied.

4.3.2 Test configuration

4.3.2.1 Test circuit diagram

ESD immunity tests shall be carried out with a transceiver without any voltage supply on a test PCB and with a minimum-wiring network according to Figure 23 and Figure 24.

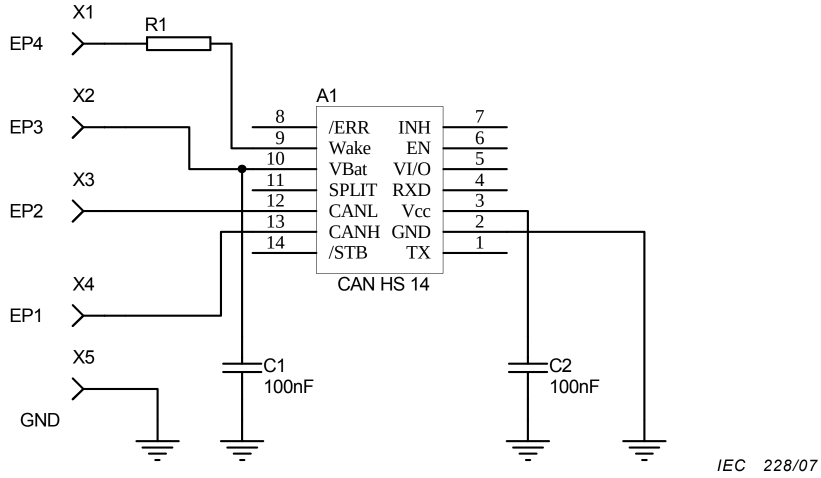

Figure 23 – Circuit diagram of the test set-up for ESD measurements at CAN high speed transceivers

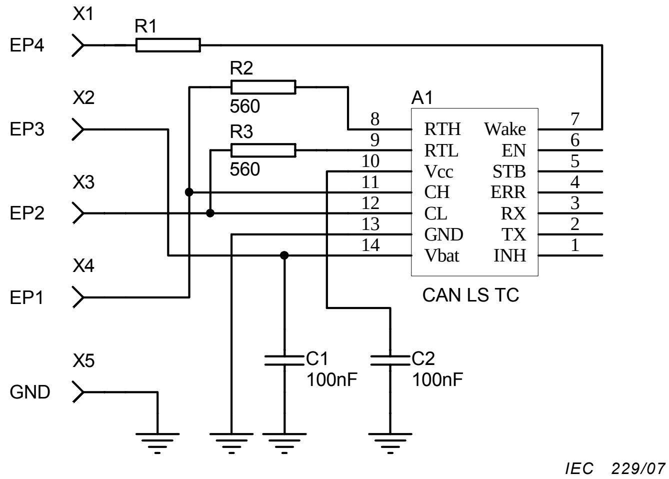

Figure 24 – Circuit diagram of the test set-up for ESD measurements at CAN low speed transceivers

- CAN transceiver

The CAN transceiver shall be tested without any voltage supply and with a minimum of external components and wiring network. The value for the series resistor on the pin wake-up (R_1) should be chosen according to the definitions of the semiconductor manufacturer with the possible minimum value (default value: 3,3 kΩ). For decoupling of the power supply lines V_{CC} and V_{Bat} ceramic capacitors (C_1, C_2 = 100 nF) shall be used.

In the test circuit for the CAN low speed system according to Figure 24 the bus termination at the pin's RTH and RTL is realized through the resistors R_2 and R_3 = 560 Ω.

For the external components assembled at the test PCB the following default values for C_1 and C_2 are defined:

- Capacity: 100 nF ± 10 %
- Material: X7R or similar
- Rated voltage: ≥ 50 V
- Type: SMD (e.g. 1206, 0805)

The resistor should be of the SMD design 1206 or 0805 with a maximum tolerance of 1 %. For both *C* and *R*, the exact type ID and manufacturer of the used capacitors and resistors are to be documented in the test report.

4.3.2.2 Coupling path of disturbances

The ESD coupling shall be implemented in a direct galvanic way by using a contact discharge module according to IEC 61000-4-2 (C = 150 pF, R = 330 Ω). For this purpose, the ESD coupling points EP 1 to 4 (see Table 19) carried out as rounded vias in the layout of the ESD test board are directly connected by a trace with the respective PIN of the transceiver.

Table 19 – Summery of ESD coupling points

Coupling point	Purpose	Components
EP1	ESD coupling for CAN_H	Direct connection
EP2	ESD coupling for CAN_L	Direct connection
EP3	ESD coupling for V_{Bat}	Direct connection
EP4	ESD coupling for wake-up	Direct connection

4.3.3 Test set-up

4.3.3.1 General

For testing ESD immunity of bus, power supply lines as well as the wake-up line (if available) measurements according to IEC 61000-4-2 shall be done. The test set-up is shown in Figure 25.

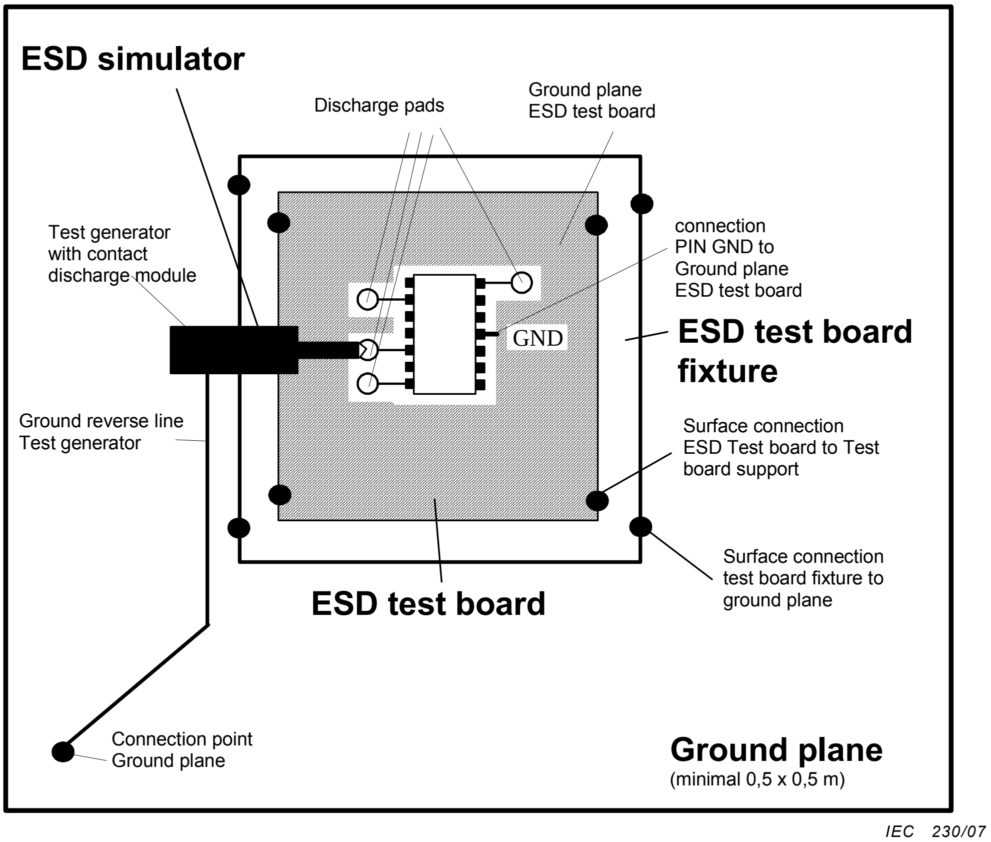

Figure 25 – Test set-up for ESD measurements

The ground plane with a minimum size of 0,5 × 0,5 m builds the reference ground plane for the ESD test set-up and shall be connected with the electrical grounding system of test laboratory. The ESD test generator ground cable shall be connected to this reference plane. The test board fixture realizes the positioning of the ESD test board and the electrical connection of the ESD test board ground plane with the reference ground plane. This connection must have a low impedance (R < 25 mΩ) and should be built by a surface contact.

Test equipment requirements:

– ESD test generator according to IEC 61000-4-2; contact discharge module (IEC-relays) with discharge capacitor 150 pF and discharge resistor 330 Ω

– ESD test board according to Clause A.2

4.3.3.2 Coupling paths on bus, wake-up and V_{Bat} line

The ESD coupling paths are a direct galvanic connection by a trace as shown in Figure 26. During the test, the tip of the ESD test generator discharge module shall be directly contacted with one of the discharge pads EP1 to 4 of the ESD test board according to Figure 26.

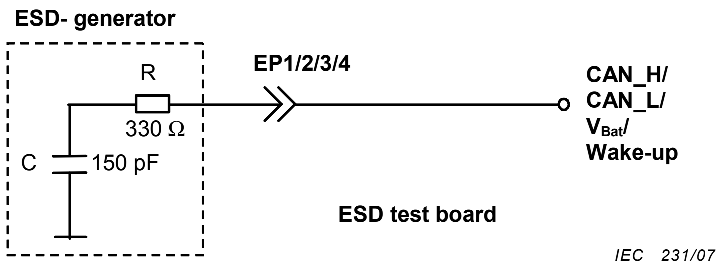

Figure 26 – Coupling network for ESD measurements on bus lines, V_{Bat} and wake-up

4.3.3.3 Test procedure and parameters

To determine transceiver immunity against ESD damage, tests according to IEC 61000-4-2 shall be done for the defined pins in Table 20 with the following parameters:

Table 20 – Specifications for ESD measurements

Item	Parameters
Type of discharge	Contact
Discharge circuit	R = 330 Ω, C = 150 pF
Discharge voltage levels	1 kV to V_{ESD_damage} (max. 30 kV)
Discharge voltage steps	1 kV up to V_{ESD} = 15 kV, then fixed values V_{ESD} = 20, 25, 30 kV
Test procedure	1) Reference measurement of functioning (bus and RX signals at communication mode) and V-I-characteristic of all pins to be tested (pin to GND) 2) 3 Discharges with positive polarity on discharge pad EP3 (V_{Bat}) with 5 s delay between the discharges 3) Connect the pin or discharge pad via a 1 MΩ resistor to the ground reference plane to get zero potential on the pin 4) Failure validation 5) Proceed with points 2) to 4) with discharge pad EP4 (wake-up) 6) Proceed with points 2) to 4) with discharge pad EP2 (CAN_High) 7) Proceed with points 2) to 4) with discharge pad EP1 (CAN_Low) 8) Proceed with point 2) to 7) with negative polarity 9) Proceed with point 2) to 9) with the next higher ESD test voltage up to damage of each tested pin If one pin is damaged, a new IC should be used for testing the other pins.
Failure validation	Function test according to 4.2.1.4.1 deviation of V-I-characteristic

The test shall be done at the specified ESD test voltages with a minimum of 3 transceivers.

The failure validation (functional test and V-I-characteristic measurement) is to be carried out on soldered transceiver. A specific test extension frame or IC adapter may be used for this purpose for contacting all needed pins of the transceiver.

5 Test report

The following items should be included in the test report.

- Schematic diagram of test configurations
- Failure criteria, used at immunity tests
- Picture or drawing of test circuit boards
- Transfer characteristics of all coupling and decoupling networks for RF and transients
- Description of test equipment
- Description of any deviation from previously defined test parameter
- Test results (see Annex B for examples for result diagrams)

Annex A
(informative)

Test circuit boards

A.1 RF and transients test

For RF and transient tests with the minimal networks a printed circuit board shall be used. To ensure good RF characteristics of the coupling and decoupling, networks for the symmetric nodes 1 to 3, and a two layer PCB as minimum should be used. The length of the coupling paths on the test board should be kept as short as possible. The trace length for IC interconnections (CAN High and CAN Low) should be shorter than 30 mm from the star point of the interconnection to the IC pins. A layout example is shown in Figure A.1.

For better shielding, all connections to the test peripheral of the test board (except for the filtered 'on'-ends for V_{Bat} and GND) should be realized through coaxial printed circuit board sockets. Layout recommendations are also given in IEC 62132-1, IEC 62132-4 and IEC 61967-1, IEC 61967-4.

The insertion losses of ports HF1 to HF3, EMI1 as well as the pulse characteristics transmitted from ports IMP1 to IMP3 to the respective transceiver signal pads at the test board shall be measured and documented in the test report.

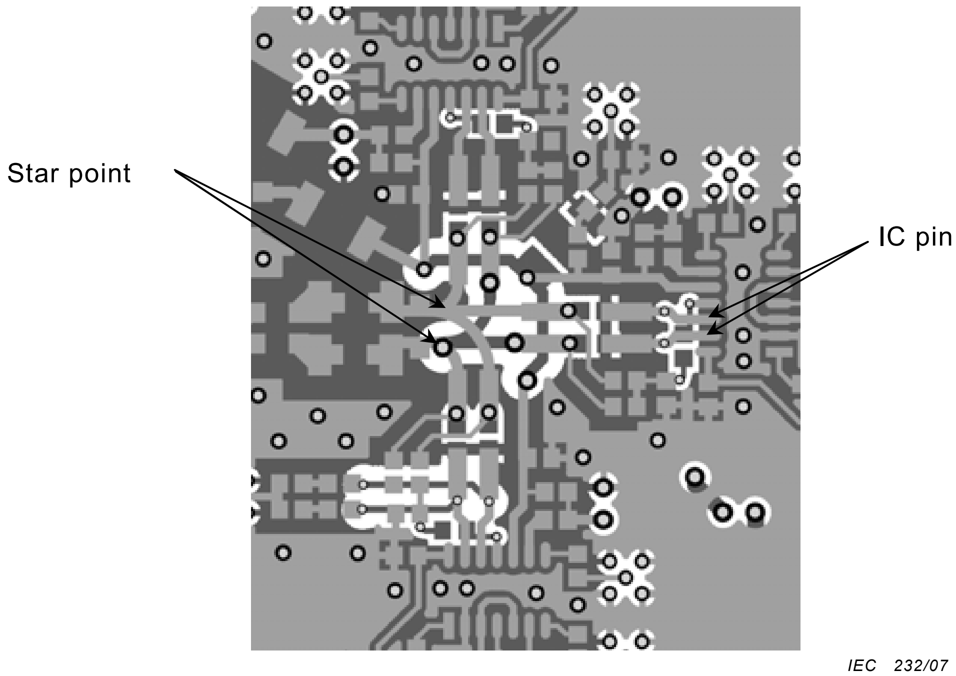

Figure A.1 – Example of IC interconnections of CAN high and CAN low

A.2 ESD test

For ESD tests, a printed circuit board shall be used. A two-layer construction of the PCB shall be chosen with extensive ground area. The pads for the discharge points EP 1 to 4 are to be carried out in such a way (e.g. as a via) that a safe contact to the discharge tip of the testing generator is guaranteed. The passive components of the minimal wiring network shall be placed in direct surrounding of the transceiver.

The insulation distance between the signal lines and pads of the passive components and the extensive ground area should be chosen in such a way that a disruptive discharge at a test voltage is impossible at these points.

Further requirements to the ESD test board are defined in Table A.1.

Table A.1 – Parameter ESD test circuit board

Parameter	Value
Trace length between transceiver pads and discharge point	(15 –0 +5) mm
Track width of the conducting path	0,254 mm (10 mil)
Substrate material	FR4
Thickness substrate	1,5 mm

The test adapter used for functional and leakage current examination makes direct contacting of the transceiver pins possible.

Annex B
(informative)

Documentation of test results

B.1 Emission of RF disturbances

An example for documentation of emission measurement results in frequency domain with a diagram is given in Figure B.1.

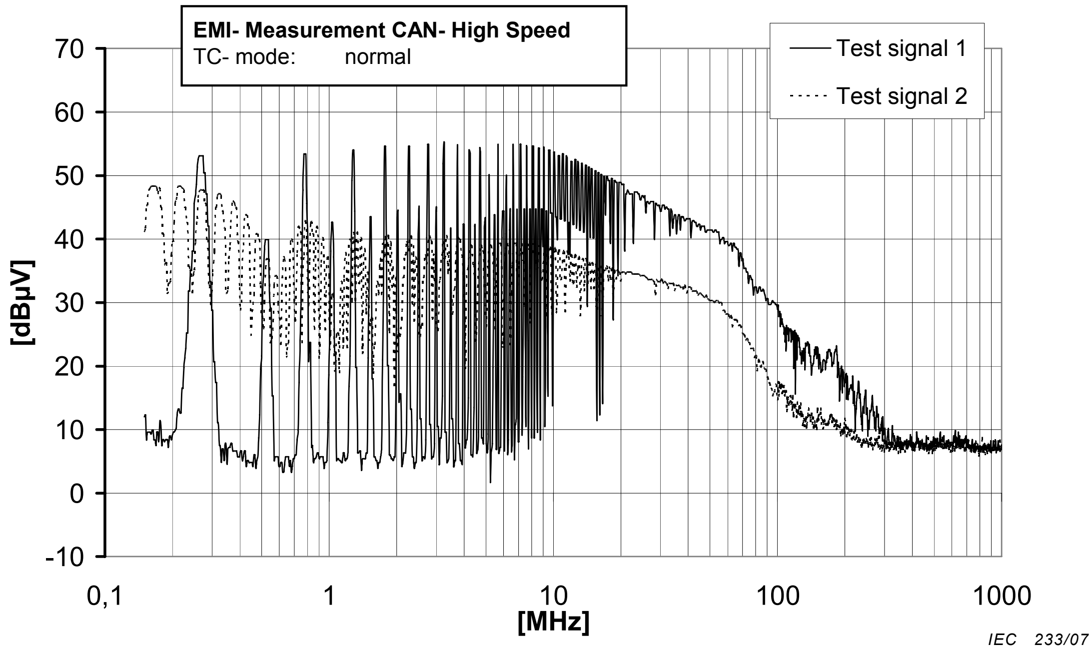

Figure B.1 – Example of presentation of emission test results in the frequency domain

B.2 Immunity to RF disturbances

An example for documentation of DPI test results in a diagram is shown in Figure B.2.

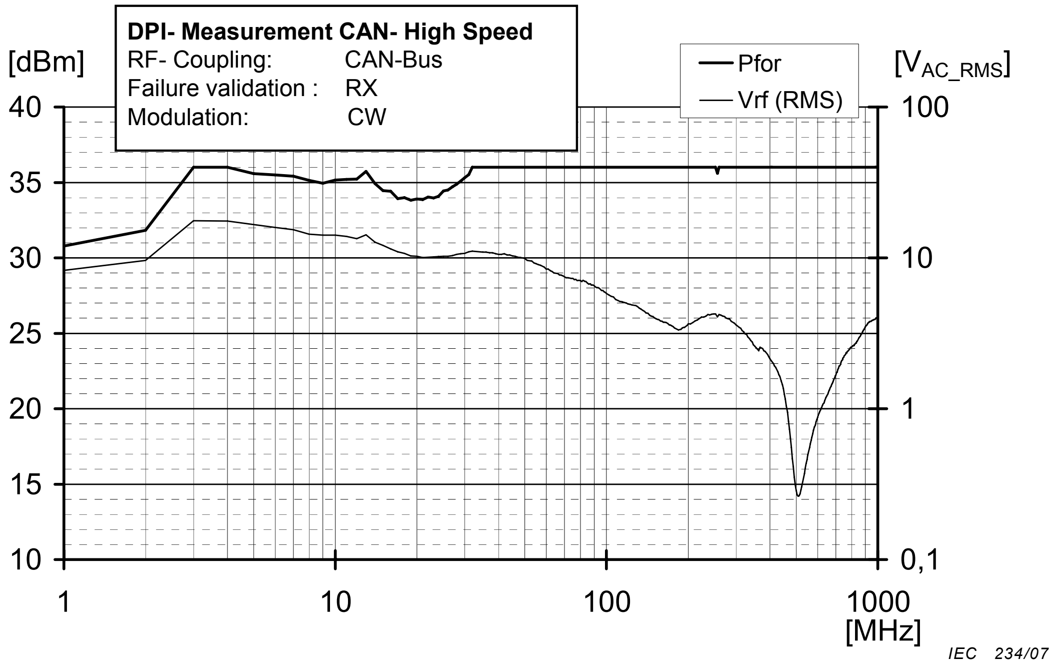

Figure B.2 – Example of presentation of DPI test results

Bibliography

IEC 61967-1, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 1: General conditions and definitions*

ISO/DIS 7637-3:2005, *Road vehicles – Electrical disturbances from conduction and coupling – Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines*

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