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INTERNATIONAL ELECTROTECHNICAL COMMISSION

TECHNICAL COMMITTEE NO. 69: ELECTRIC ROAD VEHICLES AND ELECTRIC INDUSTRIAL TRUCKS

Document for comment - IEC 61851-1

This document contains a proposition for a technical report that gives information on the Annex A of the new Edition 3 of IEC 61851-1 (presently at the CD level). It is asked of the national committees whether they accept that this document be proposed as a technical report.

The WG4 of TC69 is presently preparing Edition 3 of the IEC 61851-1 “VEHICLE CONDUCTIVE CHARGING SYSTEM – Part 1: General requirements”. It is expected that Edition 3 be published by early 2014.

Edition 2 of this standard was published in 2010 and is presently being used for the specification of charging stations. Annex A of this document gives a detailed description of the pilot wire system that controls the charging.

A certain number of minor ambiguities have become apparent during the revision process of Annex A. An incorrect interpretation of the text may impede the interoperability of all vehicles on all charging systems even if both have been designed according to Annex A of Edition 2. The new text of Annex A does not modify any basic concepts that were described in Edition 2 but only closes any loopholes in the text by a very precise description of the system in order to eliminate the risk of manufacturing incompatible systems. It also proposes a detailed test procedure.

The experts of TC69 considered that it is urgent to publish an intermediate document that contains the modified Annex A in order to ensure the interoperability all new systems that are presently designed. It was therefore decided to publish a technical report that will make the text available as quickly as possible. A draft proposition of the technical report was sent to the IEC for vote.

The IEC standardization management officers requested that the project for this technical report be first circulated as a document for comment in order to have the approval of the national committees for the further submission of this document for vote as a technical report.

The national committees are therefore requested to indicate whether they consider that the document joined can be circulated for vote as a technical report.

Any propositions as to the form of the document that should be circulated would also be welcome.

Please respond to this DC no later than 2012-10-26 via IEC Voting/Commenting system.

69/xxx/DTR

DRAFT TECHNICAL REPORT

Project number	**61851-A-TR**
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Also of interest to the following committees	Supersedes document
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Functions concerned

☒ Safety ☐ EMC ☐ Environment ☐ Quality assurance

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Title

Electric vehicle conductive charging system - Precisions on the implementation of a pilot function through a control pilot circuit using PWM modulation and a control pilot

Technical report

Electric vehicle conductive charging system –

Precisions on the implementation of a

pilot function through a control pilot circuit using PWM modulation and a control pilot

Contents

Introduction

This technical report gives precisions on the implementation of the pilot function for the charging of electric vehicles. This function is extensively described in Edition 2 of IEC 61851-1 (ELECTRIC VEHICLE CONDUCTIVE CHARGING SYSTEM – Part 1: General requirements) published in 2010.

However, the descriptions and the definitions of requirements in Annex A of this edition have proven to be insufficiently precise to ensure the absence of any misunderstanding on the exact functionality that is required. The TC69 WG4 has therefore set up a specific Ad Hoc group to clarify the text and to provide further precisions in order to ensure total interoperability of all systems that use such a pilot function. The Annex A of Edition 2 has now been completely re-written in preparation of the future Edition 3 of the IEC 61851-1. That should be available by 2014. The new text is included in the document 69/219/CD (dated 6/7/2012) as is part of the process of the revision of IEC 61851-1.

The Annex A for the new edition does not modify the basic system described in Annex A of Edition 2 (2010), but it provides a number of clarifications that should help to clear up any misunderstandings and incorrect interpretations of the previous document. It is considered that any equipment that closely follows the previous Annex A should also be compatible with the present document. The document also provides a test method for the verification of the interoperability of charging systems based on the PWM pilot function as defined in this annex.

An integral copy of Annex A presented in the document 69/219/CD is given in Annex A of this document.

The present report has been published in order to explain the main evolutions of Annex A with respect to the requirements for the pilot function using PWM modulation, as discussed within the Ad Hoc working group.

It is hoped that the early publishing of this annex will allow industry to prepare charging systems for the future generation of Electric Vehicle Supply Systems that will be compatible with the future Edition 3 thus reducing the risk of future incompatibility between systems.

Definitions of vocabulary are not included in the present document and the reader should refer to the Edition 2 for any supplementary information.

This document will be updated and published, taking into account any comments that are made on the present document or that will be made to the document 69/219/CD.

The document is to be considered as relevant until the publishing of the Edition 3 of IEC 61851-1.

Scope

This document provides an integral copy of Annex A that is to being prepared by TC69 WG4 as part of the Edition 3 of IEC 61851-1. Annex A of IEC 61851-1 describes the pilot function using PWM modulation and a control pilot wire.

Major differences with respect to Annex A of Edition 2

The new annex does not modify any fundamental aspects of the pilot function as described in Edition 2. It is however recommended that the annex of this document be studied carefully in order to verify the full conformity of any new product. The following points give an indication of the principal points that have been added or changed:

- Figures A1 and A2 have been re-drawn but do not contain any new information other than the effective position of the stray capacitances within the EVSE and the cable.
- [RA02-050] The current limit for simplified systems is defined as 10 A.
- [RA02-060] It is clearly indicated that PWM modulation of the pilot wire is required, even for simplified systems. It is not indicated that this signal should be monitored by the vehicle.
- [RA02-090] However, according to [RA02-090], the EVSE stops the delivery of power if the PWM signal value is not respected by the vehicle.
- [RA02-100] Additional components can be introduced to permit efficient high frequency data to be transmitted on the pilot wire. Complete schemas for such high frequency modulation are given in IEC/ISO 15118-3. The extra components shall have values that lie within the limits indicated in annex A so that the PWM signal will not be influenced significantly and that the Control Pilot duty cycle signal, not be deformed beyond the limits defined in Table A3.8.
- Limits have been set on the maximum peak to peak voltage of the high frequency data signal (Table A2.1) so that such signals can be easily eliminated by the measurement circuits of both the vehicle and the EVSE. Note that sustained emission of such high frequency signals will only occur if both the EVSE and the vehicle are using the high frequency data channel. There should therefore not be any difficulty for legacy systems.
- Edition 2 Table A1 has some slight changes(now Table A3.1):
    - Pulse width tolerance is tightened to +/- 5 µs
    - The maximum stray capacitance and cable capacitance is divided between maximum allowable EVSE stray capacitance and cable capacitance
    - The table contains the maximum allowable values of the additional components that may be added to enable high frequency data transmission over the pilot wire.
- Edition 2 Table A2 (now Table A3.2) has not been significant changed. The tolerance of resistors has been calculated for clarity. There is a recommendation for the use of fast diodes on the vehicle in order to improve the quality of the PWM signal.
- Table A3 of Ed2 has been replaced by a very complete set of tables
    - -Table A3.3 is informative and indicated the limits of the voltage levels that would be measured on the pilot wire if the extreme limits of all tolerances are applied to the components of the pilot wire system. It also indicates the range of the values that would be acceptable for the

definition of these states. It must be noted however that the information in this table is only informative and requirements are placed on tests as defined in A4. These tests have been devised to ensure compatibility of all pilot wire systems with all vehicles and to precisely define operational “windows” for the states of the EVSE. A further explanation is given later.

  - Table A3.4 defines turn off times for all major out-of bounds signals that could be interpreted as an absence of a pilot function and therefore require fast turn-off. Further timing is indicated in Table A3.7

  - Table A3.5 presents the main information previously contained in Edition 2 Table A3.

  - Table A3.6 clarifies the three states X1, E and F and the actions that are to be taken.

- Edition 2, Figure A3 and Table A4 have been replaced by the state diagram A3.1 and A3.2 and Table A3.7 which details all of the intermediate steps with timing information. Each transition state of the previous Figure A3 is analysed and the reasons for the transition given. This table has been established to eliminate any ambiguities that may have existed with the previous table. The sequence 11 of Table 3.7 is new optional. It is not in contradiction with the previous Annex A and has been included to allow for the vehicle send a binary information to the vehicle (e.g. for wake-up purposes).

- Edition 2 Table A5 and A6 are not changed except that it is clearly indicated that the digital data may exist even if the PWM signal is not at 5 %.

- Clause A4 is completely new and is described in following chapter.

Test criteria for pilot wire systems

A full set of tests have been described in A4 “Test procedures for immunity of EVSEs to wide tolerances on the pilot wire and the presence of high frequency data signals on the pilot wire”.

These tests have been designed on the basis of a specific test circuit that simulates the vehicle pilot wire circuit during the charging sequence. An example of one possible test circuit is given in A4.1.10.

These tests are designed to minimise test times.

The tests have been devised in order to have a range resistor values for each state that is described in Annex A. The range is sufficiently large to cater for noise and possible poor contacts, in addition to the allowable tolerances of vehicle resistors. EVSEs shall operate correctly for all the values within this range. The limits of each range are tested over a complete charging cycle, and the EVSE shall operate at both of these limits. Note that this test method implies that the results are relatively independent of the EVSE generator voltage. For each of the states the highest resistor value has been calculated on the base of the maximum allowable voltage (for example: 10 Volts for state B) with Vg = 12,6 V, R1 = 1000 Ω - 3 %). The lowest value for each range has been calculated on the basis of the minimum allowable voltage (for example: 8 Volts for state B) with Vg = 11,4 V, R1 = 1000 Ω + 3 %.

The pulse width and rise times are tested for a limited number of situations, which are deemed sufficient. The value of the internal resistor and internal voltage of the EVSE can be derived from measurements made on the pilot wire.

The influence of any imposed high frequency data carrier is tested with a specific generator system. Such tests are not given in standard EMC tests as this is an imposed signal. Further propositions are required for this test as the method presented may prove to be too long and expensive.

The test circuit

The circuit described in Figure A.4.1 has been devised to permit a smooth transition between test resistors without creating an open circuit when changing values. Resistor values have been chosen from the E192 standard resistor table to facilitate the construction of the device.

Cross reference table of figures and tables in Edition 2 and new Annex A prepared for Edition 3

Figure A1.1 – Typical control pilot electric equivalent circuit	Fig. A1	No change
Figure A1.2 –Simplified control pilot electric equivalent circuit	Fig. A2	No change
	Fig. A3	Replaced with state machine
Figure A.3.1 : State Machine Diagram for typical control pilot	New	Replaces Figure A3
Figure A3.2 : State Machine Diagram for simplified control pilot	New	Figure 301
Figure A 4.1 – Example of a test circuit	New	Non normative
Table A2.1 – maximum allowable high frequency carrier signal voltages on pilot wire.	New	
Table A3.1 – [RA02-180] EVSE control pilot circuit parameters (see Figures A.1 and A.2)	A1	
Table A3.2 – Vehicle control pilot circuit values and parameters	A2	
Table A3.3 – Pilot voltage range (informative)	New	
Table A3.4 –de-energized of the system in all cases.	New	
Table A3.5 – System states	A3	

Table A3.6 State behaviour	New A301	New table with further precisions
Table A3.7 – List of sequences	A4	This table, derived from old Figure 3, has been extensively edited to give precise descriptions for each possibility
Table A3.8 – Pilot duty cycle provided by EVSE	A5	No significant change
Table A3.9 – Maximum current to be drawn by vehicle	A6	No significant change
Table A.4.1 Test resistance values	New	New test system
Table A.4.2 - Parameters of control pilot voltages	New	New test system
Table A.4.3 – Test parameters of control pilot signals Va	New	New test system
Table A4.4 Out-of bounds resistance test	New	New test system
Table A.4.3- Position of switches	New	New test system

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Annex A
Integral copy of Annex A as prepared for Edition 3 of IEC 61851-1

Pilot function through a control pilot circuit using PWM modulation and a control pilot wire

This annex is indicated as normative for the new Edition 3 of IEC 61851-1

(Note to the reader, to be removed for the publication: it is proposed that this annex be updated with all the comments that will have been received for the CD 69/219/CD (due date 12 Oct 2012) and discussed at the next meeting in Eilat on the 19/10/2012)

A.1 General

This annex concerns all charging systems that ensure the pilot function with a pilot wire circuit with PWM modulation for Mode 2, Mode 3 and Mode 4 charging.

Two types of pilot function are available: simplified and typical.

- Simplified pilot function fulfills the requirements of 6.4.1 (ED2) 7.4.1 (ED3)
- Typical pilot function fulfills the requirements of 6.4.1 (ED2) 7.4.1 (ED3) and follows the selection of charging rate level of 6.4.1 (ED2) 7.4.2.(ED3)

This annex describes the functions and sequencing of events for this circuit based on the recommended typical implementation circuit parameters. The parameters indicated in this annex have been chosen in order to ensure the interoperability of systems with those designed according to the standard SAE J1772.

NOTE 1 This annex is not applicable to vehicles using pilot functions that are not based on a PWM signal and a pilot wire.

Note 2 Mode 4 implementation refers to IEC 61851-23.

A.2 Control pilot circuit

Figures A2.1 and A2.2 show examples of the principle of operation of the control pilot circuit.

The EVSE may cut off the power after at least 5 s in case the EV will use more current than the duty cycle allows.

Note It is recommended cut off the power with the tolerance of 10 % between the signalled pilot and measured current.

(Clarification of note for reader: systems would probably allow a 10 % tolerance above allowed current – to be removed after editing)

[RA02-010**]** Parameters of the circuit are defined in Table A3.1, Table A3.2 and section A.2.3.

[RA02-020**]** The functionality of the pilot line shall follow the requirement defined in Table A.3.5, Table A.3.7, Table A3.8, and Table A3.9.

A.2.1.1 Typical pilot electric equivalent circuit

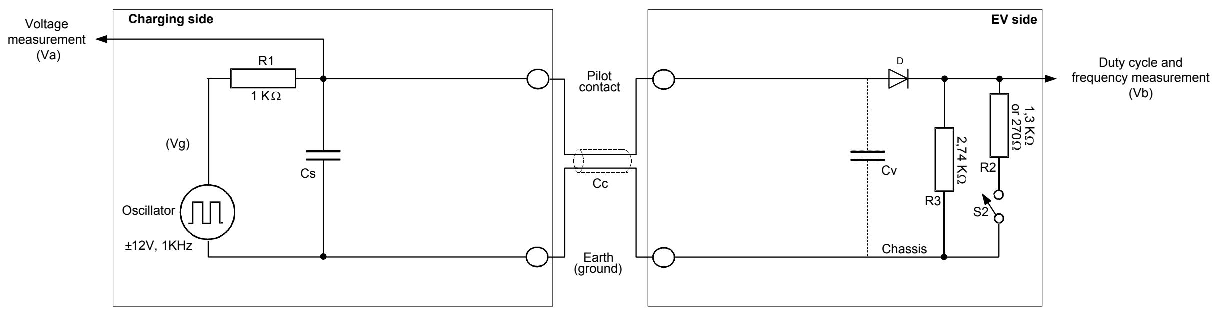


Figure A2.1 – Typical control pilot electric equivalent circuit

Note: Inductive components may be included, but are not shown in Figure A2.1.

The EVSE communicates by setting the duty cycle of a PWM signal or a steady state DC voltage of the pilot signal. (Table A3.8 and Table A3.9)

The EV communicates by loading the positive swing of the pilot signal.

Refer to Table A3.2, Table A3.3 and Table A3.5.

[RA02-030] Typical control pilot (Figure A2.1) shall support state B.

[RA02-040] Using a typical control pilot, the EV shall follow the PWM, Table A3.9.

Note The designation of R2 and R3 have been inverted with respect to Edition 2.

A.2.1.2 Simplified pilot electric equivalent circuit

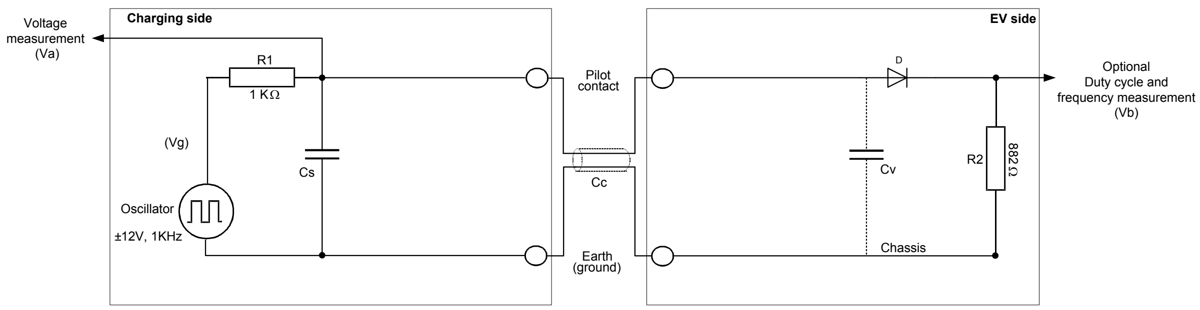


Figure A2.2 –Simplified control pilot electric equivalent circuit

NOTE Inductive components may be included, but are not shown in the Figure A2.2.

(Editing error to be corrected – replace R2 by Re)

[RA02-050] EVs, designed with simplified circuit, shall be limited to single phase charging and not exceeding 10 A.

[RA02-060] In a system that uses the simplified control pilot, the EVSE side shall modulate the PWM in the same manner as done for typical control pilot.

This circuit gives an equivalent result to the circuit shown in Figure A2.1 when the switch S2 is closed.

[RA02-070] In a simplified pilot circuit, state B does not exist.

[RA02-080] An EV, that uses simplified control pilot circuit, may not measure the duty cycle.

[RA02-090] The EVSE may cut off the power after at least 5 s in case the EV will use more current than the duty cycle value allows.

Note 1 Simplified pilot is for the EV side only; the EVSE is designed to be capable of charging to a typical and for simplified EV.

Note 2 In some countries simplified pilot is not allowed: US.

Note 3 It is not recommended to use simplified pilot for new design.

Note 4 It is recommended to cut off the power with the tolerance of 10 % between the signalled pilot and measured current.

Note 5 It is recommended for the EV, in new design, to follow the PWM.

A.2.1.3 Other requirements

[RA02-100] Additional components required for signal coupling shall not cause the Control Pilot duty cycle signal, deformed beyond the limits defined in Table A3.8 and tested as in A.4.1.6.

[RA02-110] Any impedance inserted in series with the pilot wire, at the EVSE shall not have a total inductance of more than 1 mH.

[RA02-120] Any impedance inserted in series with the pilot wire, at the EV shall not have a total inductance of more than 1 mH.

[RA02-130] Any inductive impedance inserted in series with the pilot wire shall be resistively damped to avoid high frequency oscillation of the PWM signal.

[RA02-140] When using high frequency signals for digital communication the following requirements have to be taken into account:

[RA02-150] The additional signal shall have a frequency of at least 148 kHz.

[RA02-160] The voltage of the high frequency signal shall be less than 2,5 V peak to peak for signals of more than 1 MHz. Maximum values for signals below this frequency are indicated in Table A2.1.

Table A2.1 – Maximum allowable high frequency carrier signal voltages on pilot wire

Frequency (kHz)	Max Peak/Peak voltage (V)
148-249	0,4
250-499	0,6
500-1000	1,2
> 1000	2,5

[RA02-160] The total value of additional capacitors on the EVSE required for coupling shall not exceed total of 1350 pF if the impedance to ground of that component is less than 10 kΩ.

[RA02-170] The total value of additional capacitors on the EV required for coupling shall not exceed total of 1350 pF if the impedance to ground of that component is less than 10 kΩ.

NOTE One further capacitive branch may be used for coupling signals provided the resistance impedance to ground is greater than 10 kΩ. Such capacitive/resistive branch would typically be used for signal inputs and AVC controls.

A.3 Requirements for parameters

Table A3.1 – [RA02-180] EVSE control pilot circuit parameters (see Figures A2.1 and A2.2)

Parameter[a]	Symbol	Value	Units	Remark
Generator open circuit positive voltage [c]	Voch	12,00 (± 0,6)	V	
Generator open circuit negative voltage[c]	Vocl	– 12,00 (± 0,6)	V	
Frequency	Fo	1 000 (± 0.5%)	Hz	
Pulse width [b, c]	Pwo	Per Table A3.8 (± 5 µs)	µs	
Maximum rise time (10 % to 90 %) [c]	Trg	2	µs	
Maximum fall time (90 % to 10 %)[c]	Tfg	2	µs	
Maximum settling time to 95 % steady state [c]	Tsg	3	µs	
Equivalent source resistance	R1	1 000 ± 3 %	Ω	970-1030 Ω 1% equivalent resistors commonly recommend
EVSE capacitance [d]	Cs	Max 1600 Min 300	pF	
Cable capacitance	Cc	Max 1500	pF	Case B (cord set)
EV capacitance [e]	Cv	Max 2400	pF	
Stray and additional components				
Damping resistance	Rse,Rsv	100-1000	Ω	Typical values (may be included in ferrite losses)
Optional additional series inductance	Lse	1	mH	Maximum value allowed on off board EVSE
	Lsv	1	mH	Maximum value allowed on vehicle

[a] Tolerances to be maintained over the full useful life and under environmental conditions as specified by the manufacturer.

[b] Measured at 0 V crossing of the 12 V signal.

[c] Measured at point Vg as indicated on Figure A2.1.

[d] In case C the max equivalent capacitance is total of Cc + Cs.

[e] In case A the max equivalent capacitance is total of Cc + Cv.

Note Va may be measured at the pilot terminal during state A (see A.4).

[RA03-010] Vehicle control pilot circuit values and parameters as indicated on Figures A.2.1 and A2.2 are given in Table A3.2.

Table A3.2 – Vehicle control pilot circuit values and parameters

Parameter	Symbol	Value	Value Range	Units
Permanent resistor value	R3	2,740	2658 - 2822	Ω
Switched resistor value for vehicles not requiring ventilation	R2	1,300	1261 – 1339	Ω
Switched resistor value for vehicles requiring ventilation	R2	270	261.9 – 278.1	Ω
Equivalent total resistor value no ventilation (Figure A2.2)	Re	882	856 - 908	Ω
Equivalent total resistor ventilation required (Figure A2.2)	Re	246	239 - 253	Ω
Diode voltage drop (2,75 – 10 mA, -40 °C to + 85 °C) Fast turn-off diode (Tr < 200ms) Vr > 50 V	Vd	0,7	0.55 – 0.85	V
Maximum total equivalent input capacitance	Cv	2 400	N/A	pF

[RA03-020] Value ranges are to be maintained over full useful life and under design environmental conditions.

Note 1% resistors are commonly recommended for this application.

The Table A3.3 details the pilot voltage range as a result of Tables A3.1 and A3.2 components values. These voltage ranges apply to the EVSE (Va).

Table A3.3 – Pilot voltage range (informative)

	Nominal voltage range imposed by the system			Acceptable voltage range recognized to detect the states [a]		
State / Range	**Minimum [V]**	**Nominal [V]**	**Maximum [V]**	**Minimum [V]**	**Nominal [V]**	**Maximum [V]**
States A1, A2 / positive	11.4	12	12.6	11	12	13
States B1, B2 / positive	8.37	9	9.59	8	9	10
States C1, C2 / positive	5.47	6	6.53	5	6	7
States D1, D2 / positive	2.59	3	3.28	2	3	4
State E	0	0	1	-1	0	1
States A2,B2,C2, D2 / negative State F [a]	-12.6	-12	-11.4	-13	-12	-11
a As measured at Va						

The state is valid if it is within the above values, the state detection shall be noise resistant, e.g. against EMC and high frequency data signals on the pilot wire.

Note Reliable detection of a state change may require measurements during a few milliseconds or a few PWM cycles.

[RA02-220] Compliance is tested as in A.4.

Table A3.4 – De-energized of the system in all cases

Va	Maximum Time to de-energized
>=7,5	100 ms
<=1,5	100 ms

[RA03-030] The EVSE shall open the contacts within the time indicated in Table A3.4. Compliance is tested as in A.4.

[RA03-040] The EVSE may attempt to retry the charging sequence as detailed in Figures 3 and 301.

Table A3.5 – System states

System state	EV connected to the EVSE	S2	EV ready to receive energy	EVSE ready to supply energy	EVSE supply energy	Va [a]			Remark
						High level	Low level		
A1	no	N/A	No	Not Ready	Off	12 V [d]	N/A	Steady voltage	Vb = 0 V
A2			No	Ready	Off	12 V [d]	-12 V [e]	PWM	
B1	yes	open	No	Not Ready	Off	9 V [b]	N/A	Steady voltage	R3 detected
B2			No	Ready	Off	9 V [b]	-12 V [e]	PWM	
C1	yes	closed	Yes	Not Ready	Off	6 V [c]	N/A	Steady voltage	R2 = 1,3 kΩ ± 3 % Charging area ventilation not required
C2			Yes	Ready	On	6 V [c]	-12 V [e]	PWM	
D1			Yes	Not Ready	Off	3 V [c]	N/A	Steady voltage	R2 = 270 Ω ± 3 % Charging area ventilation required
D2			Yes	Ready	On	3 V [c]	-12 V [e]	PWM	
E	yes	N/A	No	Not Ready	Off	0 V		Steady voltage	Vb = 0: EVSE or utility problem or utility power not available or pilot short to earth
F	yes	N/A	No	Not Ready	Off	N/A	-12 V		EVSE not available

[a] All voltages are measured after stabilization period.

[b] The EVSE generator may apply a steady state DC voltage or a 12 V square wave during this period. The duty cycle indicates the available current as in Table A3.8.

[c] The voltage measured is function of the value of R3 in Figure A2.1. (Indicated as Re in Figure A.2.2).

[d] 12 V static voltage

[e] The EVSE shall check pilot line low state of -12 V, diode presence, at least at the transition between B1 and B2.(or at least once before the closing of the supply switch on the EVSE).

(information to reader numbering R2 and R3 were inverted in ED2)

The state changes between A, B, C and D are caused by the EV.

The state changes between 1 and 2 are created by the EVSE.

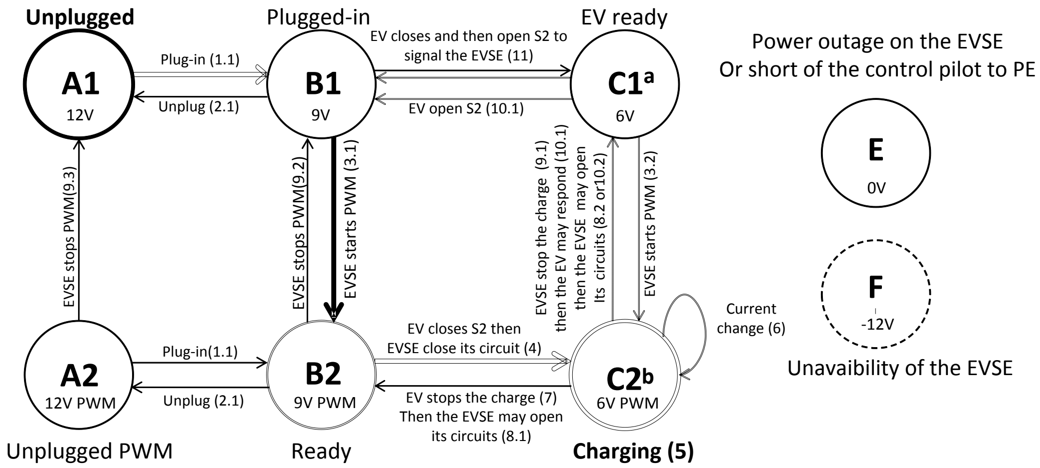
A change between state 1 and 2 indicates an availability or unavailability of power to the EV.

Table A3.6 State behaviour

States	Behaviour	Remark
X1	The EVSE is not capable to deliver the energy due to the lack of available power in the grid for charging or the EVSE intentionally stop for the intermittent charging.	If energy is available, the EVSE shall change to X2. The EV can use this as a trigger to start or resume charging.
State E	Voltage outage on the EVSE (no power to the EVSE). Short of control pilot to PE.	The EVSE unlocks the socket-outlet at maximum of 30 s, if any.
State F	Unavailability of the EVSE	The EVSE unlocks the socket-outlet at maximum of 30 s, if any.

It is not recommended to use the F state to signal unavailability of energy to the EV. State X1 gives the same information.

The State E may be caused by any number of difficulties and shall not be used as a signalling state to convey specific information.



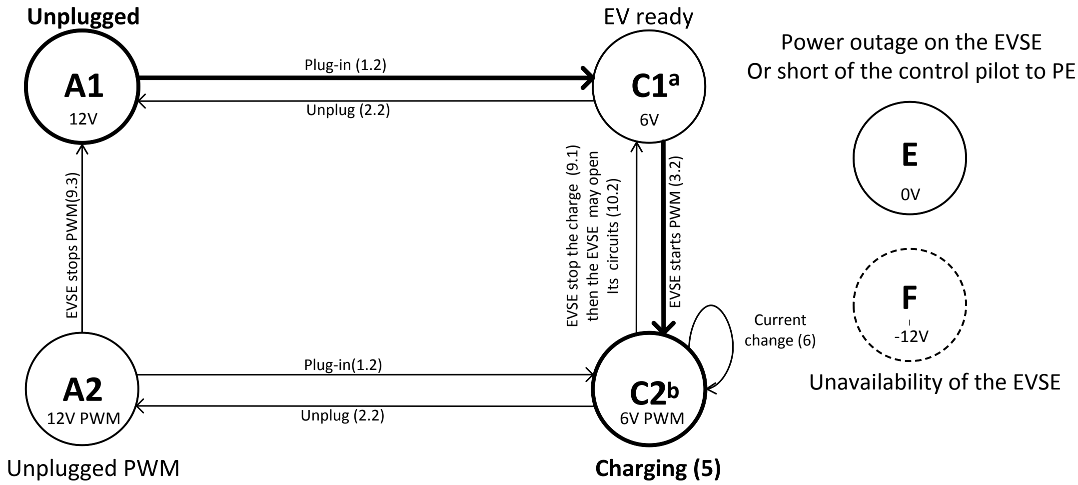
[a] Can be state D1, 3V.

[b] Can be state D2, 3V PWM.

Note: A change from any state to state Ax may take place at any time.

(xx) Is the sequence reference.

Figure A.3.1 - State Machine Diagram for typical control pilot



[a] Can be state D1, 3V.

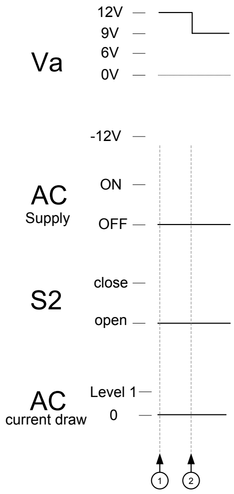
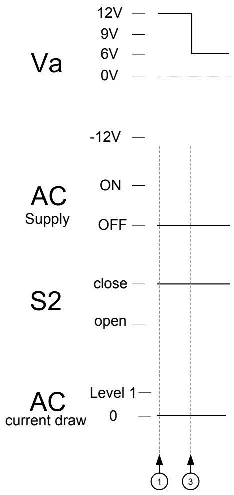
[b] Can be state D2, 3V PWM.

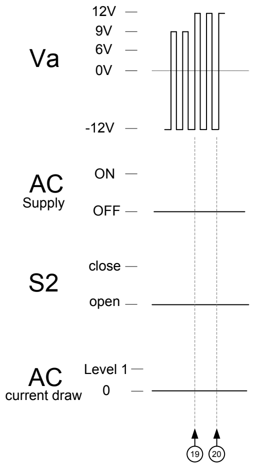
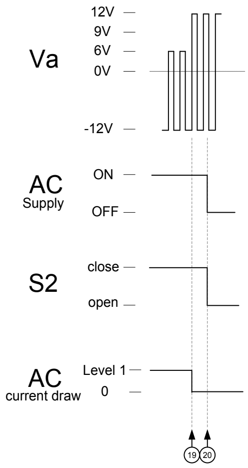
Note: A change from any state to state Ax may take place at any time.

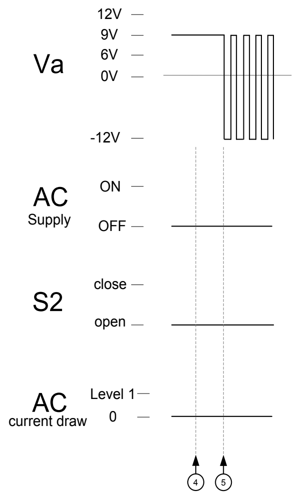
(xx) Is the sequence reference.

Figure A3.2 - State Machine Diagram for simplified control pilot

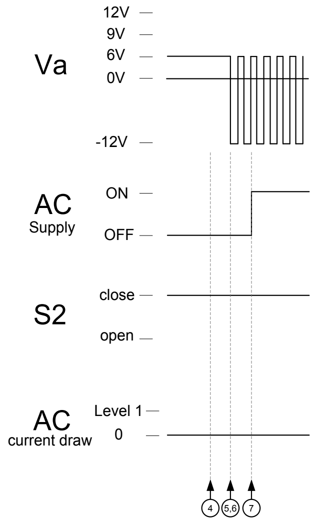
Table A3.7 – List of sequences

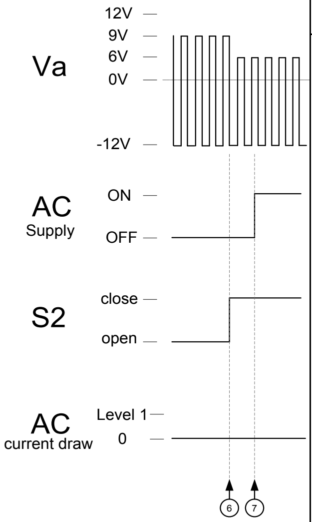
Sequence		State or transition	Conditions	Timing
1.1 Plug-in (With S2)		A1	(1) EV not connected + 12 V	t_{1-2} No Max (3)
		A1→B1	(2) The cable assembly is connected to the vehicle and to the EVSE, + 9 V. Note This sequence is also applicable from A2→B2.	
1.2 Plug-in (w/o S2)		A1	(1) EV not connected + 12 V	t_{1-3} No Max (3)
		A1→C1/D1	(3) The cable assembly is connected to the vehicle and to the EVSE, + 6 V. Note This sequence indicates EV operates in simplified pilot function. Note This sequence is also applicable from A2→C2/D2. Note t2 does not exist in this sequence.	

2.1 Unplug at state Bx		B2→A2 or B1→A1	(19) Plug disconnected from the EVSE or EV connector disconnected from the inlet. Delay for turning off the square wave oscillator after transition from state B2, C2 or D2 to state A1.	$T_{19\text{-}20}$ No Max (3)
		A1 or A2	(20) EV not connected The EVSE unlocks the socket outlet at maximum of 5 s, if any In case A, EV with attached cable, a switch may be added on the pilot line, on the EV side (cable, plug, vehicle), to simulate the EV disconnection (state A).	
2.2 Unplug during charging		C2, D2 → A1 or C2, D2 → A2	(19) Plug disconnected from the EVSE or EV connector disconnected from the inlet during charging, the EVSE circuits shall be open under load.	Max 100 ms
		A2 → A1	Delay for turning off the square wave oscillator	No Max (3)
		A1 or A2	(20) EV not connected The EVSE unlocks the socket outlet at maximum of 5 s, if any. ~~In case A, EV with attached cable, a switch may be added on the pilot line, on the EV side (cable, plug, vehicle), to simulate the EV disconnection (state A).~~	

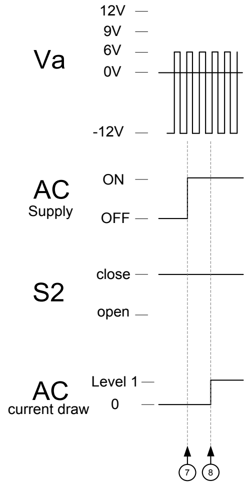
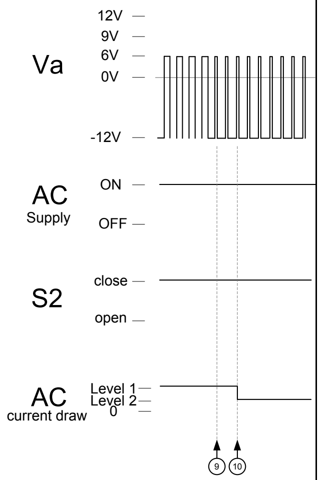
<table>
<tr>
<td>3.1
EVSE Power available
(state B)</td>
<td></td>
<td>B1→B2</td>
<td>(5) The EVSE is now able to supply power, and indicates the available current by the PWM duty cycle.

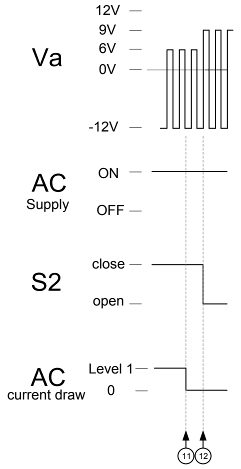
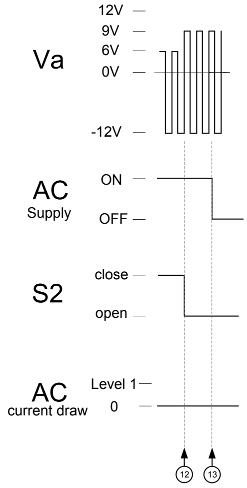
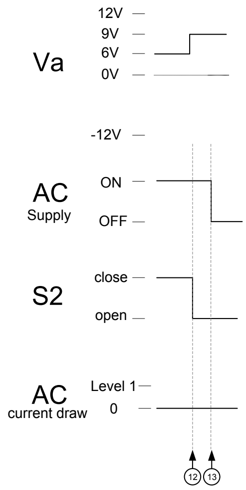
The EV shall recognize the change of state from B1 to B2.

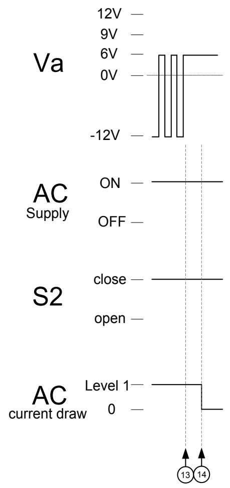
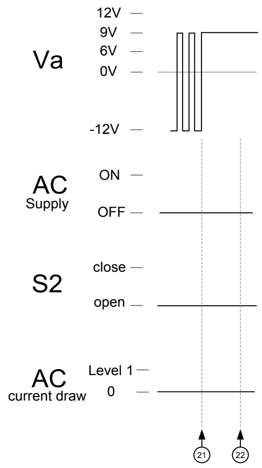
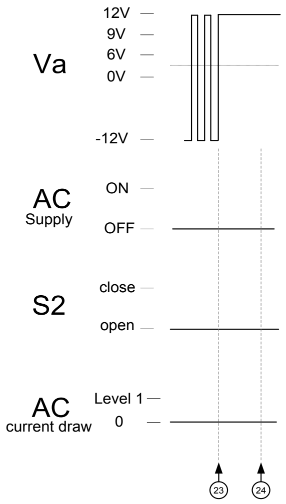
Note This sequence can take place in the beginning of a charging or to resume of a charging session.</td>
<td>t_{4-5}
No Max
(3)</td>
</tr>
<tr>
<td rowspan="2">3.2
EVSE Power available
(state C)</td>
<td rowspan="2"></td>
<td rowspan="2">C1→C2</td>
<td>(5) The EVSE is now able to supply energy, and indicates the available current by the PWM duty cycle.

Note In this sequence EVSE can assume EV operates in simplified control pilot and may not follow the current limitation indication by PWM.</td>
<td>t_{4-5}
No Max
(3)</td>
</tr>
<tr>
<td>(6) The EV is ready to receive energy.
(7) EVSE energizes the system. If state D2 is detected, the supply will close only if ventilation requirements are met.</td>
<td>t_{5-6}
0s
t_{6-7}
Max 3 s</td>
</tr>
<tr>
<td rowspan="2">4
EV ready to charge</td>
<td rowspan="2"></td>
<td>B2→C2,D2</td>
<td>(6) The EV is ready to receive energy.</td>
<td rowspan="2">t_{6-7}
Max 3 s</td>
</tr>
<tr>
<td>C2,D2</td>
<td>(7) EVSE energizes the system. If state D2 is detected, the supply will close only if ventilation requirements are met.

In case of an EV asks for ventilation delay, ventilation command turns on after transition from state C2 to state D2 in 3 s. in case the EVSE does not have ventilation, it shall open its circuits and may change to state x1.</td>
</tr>
</table>

5 EV starts charging		C2,D2	(8) Current drawn by the EV.	t_{7-8} Min 100 ms
6 Current change		C2,D2	(9) The EVSE indicates for power adjustment. Such a demand may originate from the grid or by manual setting on EVSE. The duty cycle can be changed at any time to any valid duty cycle. In normal operation, during the 5 s of the adjustment, the EVSE shall not use sequence 6 for changing the PWM.	10 s From initiation (EVSE gets the status) till EV responds
			(10) The EV adjusts the maximum current draw to be equal or below the PWM. The EV shall answer to this change.	t_{9-10} Max 5 s

7 EV stops the charge		C2, D2	(11) In normal operation an EV shall decrease the current draw to minimum (less than 1 A) before opening S2. During a non normal operation (emergency) the EV may open S2 immediately.	$t_{11\text{-}12}$ No Max (3)
		C2,D2 → B2	(12) The EV opens S2.	
8.1 EVSE responds to EV, opens S2 (with PWM)		B2	(13) The EVSE opens its circuit in response to the opening of S2 (considered as abnormal situation, S2 may open under load)	$t_{12\text{-}13}$ Max 100 ms
8.2 EVSE responds to EV, opens S2 (w/o PWM)		B1	(13) The EVSE shall open its circuit in response to the opening of S2	$t_{12\text{-}13}$ Max 100 ms

9.1 EVSE requests to stop charging		C2,D2→C1,D1	(13) EVSE may adjust the duty cycle to steady state in order to indicate the EV to stop the current draw.	t_{13-14} Max 3 s
		C1,D1	(14) The EV may respond to the steady state PWM, and stops the current draw.	
		In case the EV will not follow the PWM the EVSE may open its circuits.		
9.2 EVSE stops PWM at state B		B2 → B1	(21) EVSE may stop the PWM at any time. (22) No action by the EV needs to take place. In case sequence 3.1 will follow sequence 9.2, the EVSE shall wait at least 3 s.	T_{21-22} No Max
9.3 EVSE stops PWM at state A		A2 → A1	(23) EVSE may stop the PWM at any time. (24) No action by the EV needs to take place.	T_{23-24} No Max

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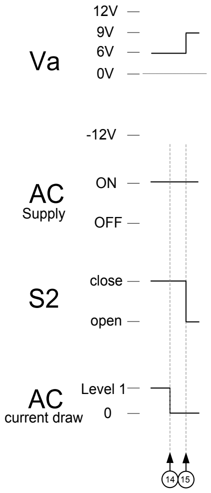
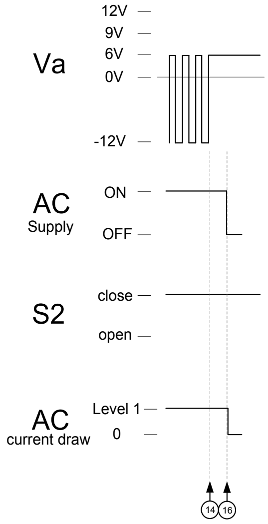
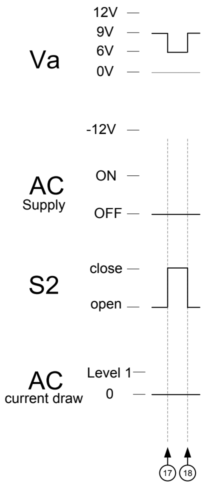
10.1 EV responds to stop charging request		C1,D1	(14) The EV may respond to the steady state PWM, and stops the current draw.	t_{14-15} Max 3 s
		C1,D1→B1	(15) The EV opens S2.	
		This sequence shall be followed by sequence 8.2		
10.2 EV does not respond to a stop charging request		C1,D1	(14) The EV does not respond to the steady state PWM, and does not stop the current draw.	t_{14-16} Min 3 s Max 5 s
		C1,D1	(16) The EVSE shall open its circuit under load (timer starts upon the PWM change)	
		Note t_{15} does not exist due to no S2 in this sequence.		
11 EV signal to the EVSE		Bx→Cx, Dx→Bx	(17, 18) A transition from state Bx to Cx, Dx and Cx, Dx to Bx. The EVSE shall not move to state F due to sequence 11. This sequence is optional, and shall be used for the digital communication. This sequence may be used by the EV in order to signal the EVSE. (e.g. wakeup). In any case the EV shall not draw current during this sequence.	t_{17-18} Min 200 ms Max 3 s
12		XX→E XX→F	Changing from any state to state E, the EVSE circuit shall be open.	Max 100 ms
			EV shall open S2, if any.	Max 3 s
			The EVSE unlocks the socket-outlet if any.	Max 30 s
Note 1 The cutoff power (stops the PWM signal) can take place up to 5 times during charge session. Note 2 It is recommended that the EVSE will resume the PWM on the EV request (sequences 4 and 11). Note 3 The indication “no maximum” implies that the delay time has no constraints and may depend on external influences and the conditions existing on the EVSE or the EV.				
If locking is used, the EVSE shall lock the socket-outlet at least before energizing the EV, The EVSE shall allow removal of the plug when entering state A (sequence 2, case B).				

Table A3.8 – Pilot duty cycle provided by EVSE

Nominal duty cycle provided by EVSE	Available line current
0 % Duty Cycle	EVSE not available - F
5 % Duty Cycle	A duty cycle of 5 % indicates that digital communication is required and shall be established between the EVSE and EV before charging
(% duty cycle) = current[A] / 0,6 10 % ≤ duty cycle ≤ 85 %	Current from 6 A to 51 A:
(% duty cycle) = (current[A] / 2,5) + 64 85 % < duty cycle ≤ 96 %	Current from 51 A to 80 A:
100 % Duty Cycle	Current not available – X1

Note Duty cycle tolerances are indicated in Table A3.1.

Table A3.9 – Maximum current to be drawn by vehicle

Nominal duty cycle interpretation by vehicle	Maximum current to be drawn by vehicle
Duty cycle < 3 %	Charging not allowed (0A)
3 % ≤ duty cycle ≤ 7 %	A duty cycle of 5 % indicates that digital communication is required and shall be established between the EVSE and EV before charging. Charging is not allowed without digital communication. Digital communication may also be used with other duty cycles.
7 % < duty cycle < 8 %	Charging not allowed (0 A)
8 % ≤ duty cycle < 10 %	6 A
10 % ≤ duty cycle ≤ 85 %	Available current = (% duty cycle) × 0,6 A
85 % < duty cycle ≤ 96 %	Available current = (% duty cycle - 64) × 2,5 A
96 % < duty cycle ≤ 97 %	80 A
Duty cycle > 97 %	Charging not allowed (0A)
If the PWM signal is between 8 % and 97 %, the maximum current may (shall ?) not exceed the values indicated by the PWM even if the digital signal indicates a higher current. In 3-phase systems, the duty cycle value indicates the current limit per each phase. The current indicated by the PWM signal shall not exceed the current cable capability and the EVSE capability, the lower between them applies. Note The EV should respect 6 A as lower value of the PWM.	

A.4 Test procedures for immunity of EVSEs to wide tolerances on the pilot wire and the presence of high frequency data signals on the pilot wire

A.4.1.1 General

Testing is done using an EV simulator on the pilot wire that allows the testing in normal operation and at the tolerance limits allowed for the voltage and including the imposition of a high frequency signal on the pilot wire. The test scheme described in this clause allows the testing of the EVSE when in normal operation and when subjected to high frequency imposed signals on the pilot wire.

RA04-010] Car simulator shall have the possibility of testing the EVSE with all three possible resistors, and 3 further out of bounds values as indicated in Table A4.1 with the following values for the other components.

- Cv will use the maximum value from Table A3.1 (including the 1000 pF of the generator).
- Lsv will use the maximum value only from Table A3.1
- Rsv will use the minimum value from Table A3.1
- Cc will use the maximum value from Table A3.1
- The high frequency test signal shall be injected at the EVSE outlet for cases A and B, and at the coupler for case C
- The diode shall be conform with the specifications in Table A3.2
- Resistor values shall be within a tolerance of 0,25 % of the value indicated in Table A4.1

Table A.4.1 - Test resistance values

	R3 (Ω)	R2 (Ω)	R4 (Ω)
Maximum Value	3288	1040	324
Nominal Value	2740	1300	270
Minimum value	2192	1040	216
Out of bound 1.5v	2740	78	
Out of bound 7.5v	2740	3370	

NOTE 1: This table is not applicable to values used on vehicles (see Table A3.1).

NOTE 2: An example of a test setup is described in A4.4 Figure A4.1.

A.4.1.2 Test procedure

[RA04-020] The proper function of the EVSE shall be tested under the following conditions:

[RA04-030] A sine wave generator with an impedance of 50 Ω is connected to the control pilot line via a 1000 pF capacitor.

[RA04-040] The output amplitude of the sine wave generator is set so that the high frequency voltage component on the pilot wire is 1 V peak.

The control of the imposed high frequency test component voltage shall be measured on the coupler as close as possible to the EVSE.

During the test it is necessary to adjust the voltage of the generator.

[RA04-050] The frequency of the sine wave generator shall sweep through the frequency range from 1 MHz to 30 MHz with a logarithmic step width of 4 % and a holding time of 0,5 s.

[RA04-060] Unless otherwise specified, input voltage from power supply shall be the rated value, within the range of its tolerance.

[RA04-070] Unless otherwise specified, the tests shall be carried out in a draught-free location and at an ambient temperature of 20 °C ± 5 °C.

[RA04-080] The tests shall be carried out with the specimen, or any movable part of it, placed in the most unfavourable position which may occur in normal use.

Note The measure of the control pilot wire will take place on the EVSE coupler in case A and case B, and on the EV coupler in case C.

A.4.1.3 Test list

A.4.1.4 Oscillator frequency and generator voltage test

[RA04-090] R2, R3, and R4 shall be at the nominal value for this test.

[RA04-100] The voltage measured at the EVSE output shall be as given in Table A.4.2.

Table A4.2 - Parameters of control pilot voltages

	Minimum	Maximum
States A1, A2 / positive	11,4	12,6
States B1, B2 / positive	8,28	9,32
Negative	-12,6	-11,4

The Internal resistor of the EVSE (R1) value is calculated by the formula

R(EVSE) = 2740 * (Vstate_a –Vstate b)/VR2

Where Vstate a and Vstate b are the two positive voltage values measured during the test of Table A4.2 and VR2 is the value of the positive voltage across R2 in state B.

[RA04-110] R(EVSE) shall be 1000 Ω ± 4 %.

[RA04-120] The precision of measurements of voltages for this test shall be better than ± 0,5%.

A.4.1.5 State B2 or C2 - Check the Frequency (1 kHz).

[RA04-130] The frequency shall be within ± 0,5% of 1000 Hz.

[RA04-131] R2, R3 and R4 shall be at the nominal value for this test.

A.4.1.6 Duty cycle test

[RA04-140] Duty cycle should be tested at 5 %, 10 % and the maximum current declared by the EVSE manufacturer (in case the EVSE cannot change the PWM it will be tested only at the default duty cycle).

[RA04-141] R2, R3 and R4 shall be at the nominal value for this test.

A.4.1.7 Pulse wave shape test

[RA04-150] The PWM pulse shape shall be within the values indicated in Table A.4.3.

[RA04-151] R2, R3 and R4 shall be at the nominal value for this test.

Table A.4.3 – Test parameters of control pilot signals Va

Parameter		Value	Unit
Maximum Rise time (10 to 90 %)	State B	10	μs
	State C	7	μs
	State D	5	μs
Maximum Fall time (90 to 10 %)	States B, C, D	13	μs
NOTE Signals are evaluated in the range of nominal resistance in the control pilot test circuit in Table A.4.1			

A.4.1.8 Sequences diagnostic – normal charge cycle

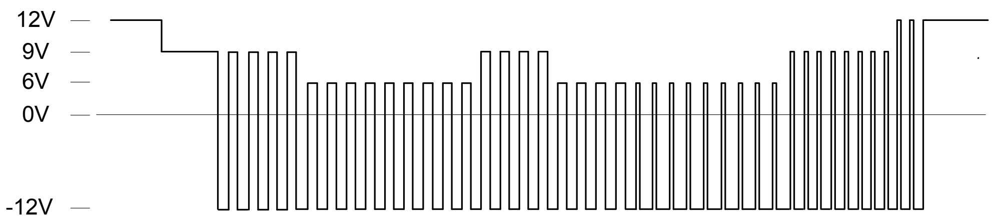
This test checks the AC supply and the timing in order to test the operation at the maximum and minimum allowed voltage levels.

[RA04-160] In case the EVSE cannot change the PWM, there is no need to meet sequence 6.

All sequences need to be checked with the timing according to Table A3.7.

There is a need to wait minimum of 20 s between sequences.

a. Normal operation
   i. 1.1 --> 3.1 --> 4 --> 7 --> 4 --> 6 --> 7 --> 8.1 --> 2.1.



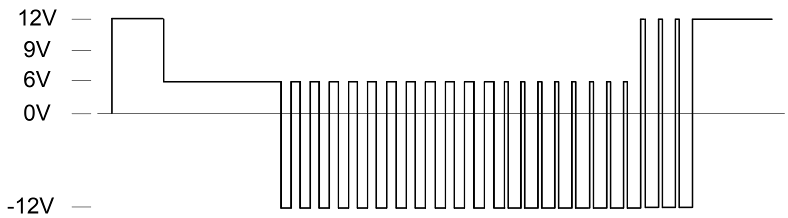
[RA04-170] *Unlocking of the coupler in the EVSE, if any, needs to take place according to Table A3.6.

[RA04-180] Four complete standard charging cycles shall be performed using the resistor values indicated in Table A.4.1. The EVSE shall be deemed to have failed the test if the cycle is not completed.

Table A.4.4 - Normal charge cycle test

	R3 (Ω)	R2 (Ω)	R4 (Ω)	HF voltage
Test 1	3288	1560	324	Not present
Test 2	3288	1560	324	present
Test 3	2192	1040	216	Not present
Test 4	2192	1040	216	present
Note 1 Resistances tolerance at least ± 0,2 %. Note 2 Reference R4 is used for the resistance value if ventilation is required. Note 3 HF voltage test is only required for EVSEs designed for PLC communication Lower voltages may apply for EVSEs not designed for PLC systems.				

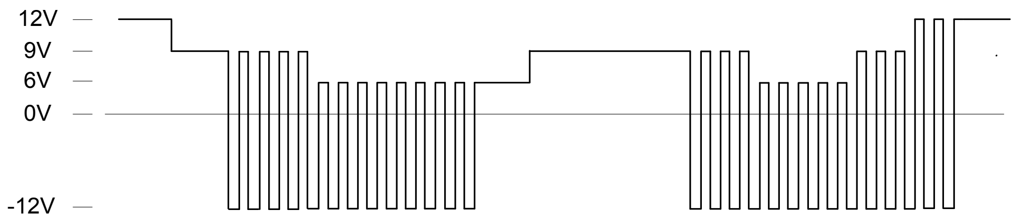
ii. For simplified control pilot supported EVSE
1.2 --> 3.2 --> 5 --> 6 --> 2.2.



[RA04-170] Optional charge cycle test for vehicles that support grid management

These tests are done using the nominal values of R2, R3 and R4 as given in Table A4.1.

1.1 --> 3.1 --> 4 --> 9.1 --> 10.1 --> 8.2 --> 3.1 --> 4 --> 8.1 --> 2.1



[RA04-180] During sequence 4, go to state E and unplug the power from the EVSE.

Note Sequence 8.2 will take place just after sequence 10.1 with no waiting time.

A.4.1.9 Test of out of bounds values of the voltage

[RA04-200] The 6 sequences of tests indicated in Table A.4.4 shall be performed.

[RA04-210] The EVSE shall open the supply contacts when the out of bounds voltage values are detected.

[RA04-211] The out of bounds voltages are created by using intermediate resistances values.

[RA04-212] Test shall be initiated with R2, R3 and R4 at the nominal value.

Table A4.5 Out-of bounds resistance test

Test	State A	State B	State C	Resultant test voltage (informative)	
1	R3 at nominal value R2 = 3364	R2 = 3364	R2 = 3363	7,5V	EVSE shall go back to “B/C”1 state (stop PWM), The contactor shall remain open error may be indicated on EVSE screen
2	R2, 3 at nominal values	R2, 3 at nominal values	R2 at nominal value then R2 = 3363	7,5V	After 100 ms max EVSE shall open contact and go to error state
5	R2, 3 at nominal values	R2, 3 at nominal values	R2 at nominal value then R2 = 78	1,5V	After 100 ms max EVSE shall open contact and go to error state

A.4.1.10 Example of a test simulator of the vehicle (not normative)

Figure A4.1 gives an example of a possible test circuit that allows the simulation of the electric vehicle during charge. The switching of the resistor values allows the extreme voltage values to be tested according to Table A4.1. The signal generator simulates the presence of an imposed high frequency data carrier.

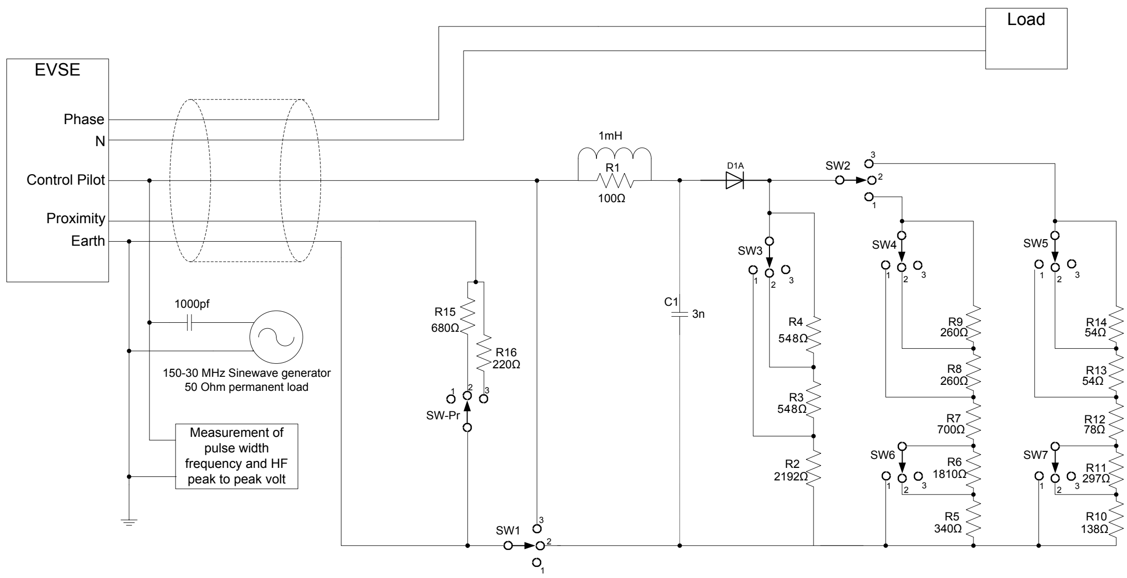


Figure A 4.1 – Example of a test circuit

Note 1 It is recommended to use of metal coated resistors with 0,2 % tolerance or better.

Note 2 Resistor values have been chosen to correspond to the E192 value table.

Note 3 High quality (gold plated contact) switches are recommended.

Note 4 A fast turn off diode of type BDA 16 is recommended (to be defined).

Note 5 Cable length is less than 3 m.

Table A.4.6 gives the switch positions for the different operation conditions. It allows the simulation of the complete test cycles using the nominal resistances, or the tolerance limit values of the EV resistances. Out of bound values can also be created.

For tests at nominal values, SW1 and SW2 are used to switch between states A, B, C and D. Nominal values of the resistance are obtained with SW3, SW4, SW5, SW6 and SW7 in position 2.

Table A4.6 - Position of switches

State		Proximity	SW1	SW2	SW3	SW4	SW5	SW6	SW7
A	Unplugged	1 (open)	1	X	X	X	X	X	X
Earth fault*	Open earth wire	X	1	X	X	X	X	X	X
E*	Pilot wire short circuited	X	3	X	X	X	X	X	X
B	Nominal value	2	2	2	2	X	X	X	X
C	Nominal value	2	2	1	2	2	X	2	X
D	Nominal value	2	2	3	2	X	2	X	2
B	Upper values	2	2	2	3	X	X	X	X
C		2	2	1	2	3	X	2	X
D		2	2	3	2	X	3	X	2
B	Lower value	2	2	2	1	X	X	X	X
C		2	2	1	2	2	X	1	X
D		2	2	3	2	X	2	X	1
C	7,5 V out of bounds	2	2	1	2	3	X	3	X
D	1,5 V out of bounds	2	2	3	2	X	1	X	1