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Electric vehicle conductive charging system –
Part 1: General requirements

Système de charge conductive pour véhicules électriques –
Partie 1: Règles générales

IEC 61851-1:2010

Annex A
(normative)

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

A.1 General

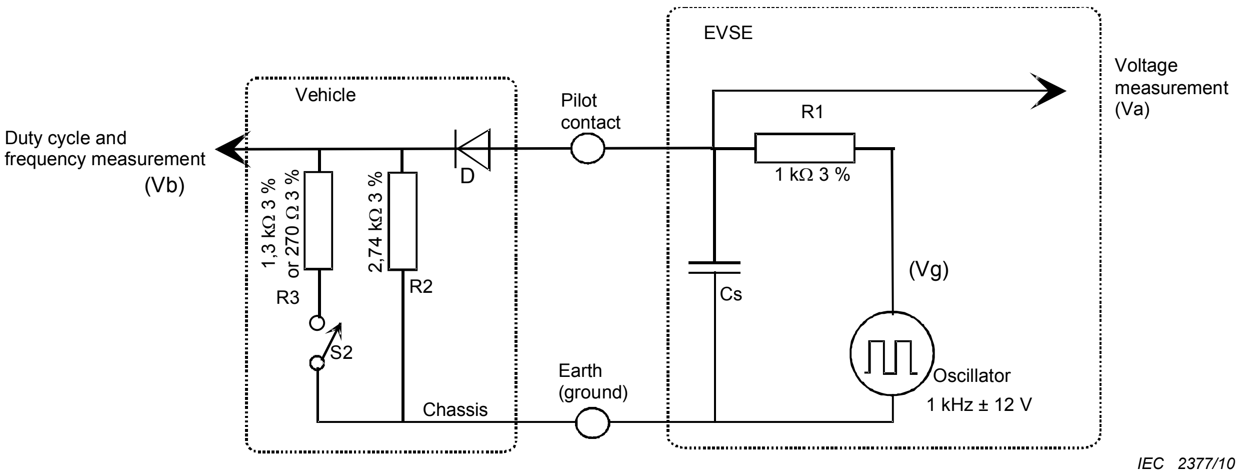
This annex concerns all charging systems that ensure the pilot function with a pilot wire circuit with PWM modulation in order to define the available current level for mode 2 and mode 3 charging. This annex describes the functions and sequencing of events for this circuit based on the recommended typical 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 This annex is not applicable to vehicles using pilot functions that are not based on a PWM signal and a pilot wire.

A.2 Control pilot circuit

Figure A.1 and A.2 show the basic principle of operation of the control pilot circuit.

Parameters of the circuits are defined in Table A.1, Table A.2, Table A.3, Table A.5, Table A.6, and Table A.7.



NOTE Stray capacities (Cv and Cc) between pilot and earth are not shown on figure (see Tables A.1 and A.2).

Figure A.1 – Typical control pilot circuit

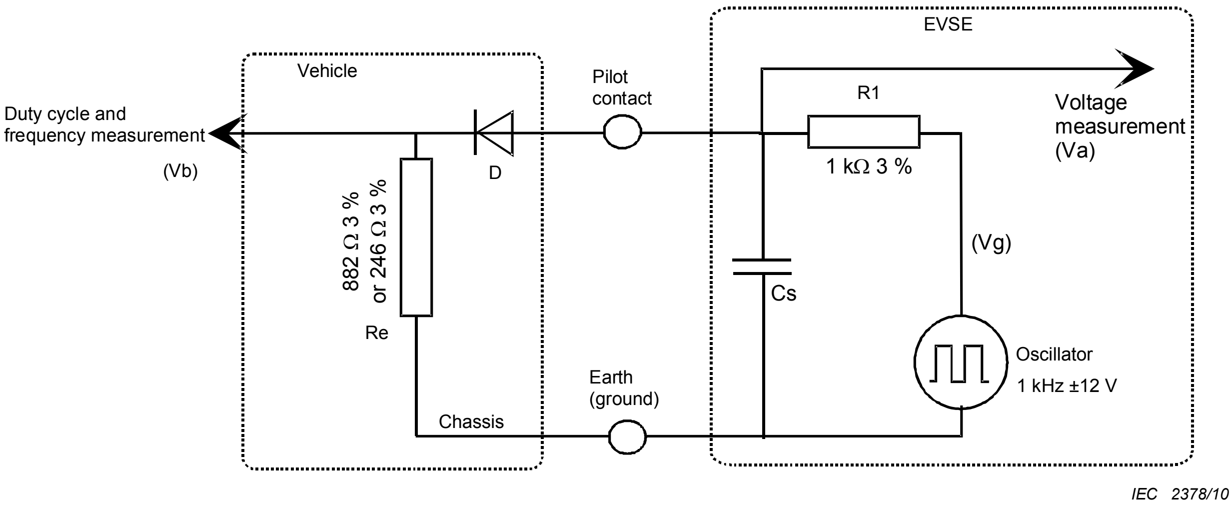


Figure A.2 – Simplified control pilot circuit

The simplified circuit shall not be used for vehicles drawing more than 16 A single phase. It shall not be used with 3-phase supply.

NOTE This circuit gives an equivalent result to the circuit shown in Figure A.1 when the switch S2 is closed. The simplified control pilot circuit cannot create vehicle states A and B as defined in Table A.3.

Table A.1 – EVSE control pilot circuit parameters (see Figures A.1 and A.2)

Parameter[a]	Symbol	Value	Units
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 A.4 (± 25 µs)	µs
Maximum rise time (10 % to 90 %) [c]	Trg	2	µs
Maximum fall time (90 % to 10 %)[c]	Tfg	2	µs
Minimum settling time to 95 % steady state [c]	Tsg	3	µs
Equivalent source resistance[c]	R1	1 000 ± 3 %	Ω
Recommended EMI suppression	Cs	300	pF
Maximum total cable[d] capacity + Cs	Cs + Cc	3 100	pF

[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 A.1.

[d] Typical vehicle cord capacities (Cc) should be minimized and less than 2 000 pF.

Table A.2 – Vehicle control pilot circuit values and parameters (see Figures A.1, A.2)

Parameter	Symbol	Value	Units
Permanent resistor value	R2	2,74 k (± 3 %)	Ω
Switched resistor value for vehicles not requiring ventilation	R3	1,3 k (± 3 %)	Ω
Switched resistor value for vehicles requiring ventilation	R3	270 (± 3 %)	Ω
Equivalent total resistor value no ventilation (Figure A.2)	Re	882 (± 3 %)	Ω
Equivalent total resistor ventilation required (Figure A.2)	Re	246 (± 3 %)	Ω
Diode voltage drop (2,75 – 10 mA, -40 °C to + 85 °C)	Vd	0,7 (± 0,15)	V
Maximum total equivalent input capacity	Cv	2 400	pF

Tolerances are to be maintained over full useful life and under design environmental conditions.

Table A.3 – Pilot functions

Vehicle state		Vehicle connected	S2	Charging possible		Va [a]	
A		no	open	no		12 V [d]	Vb = 0 V
B		yes	open	no		9 V [b]	R2 detected
C		yes	closed	Vehicle ready		6 V [c]	R3 = 1,3 kΩ ± 3 % Charging area ventilation not required
D						3 V [c]	R3 = 270 Ω ± 3 % Charging area ventilation required
E		yes	open	no		0 V	Vb = 0: EVSE, utility problem or utility power not available, pilot short to earth ...
F		yes	open	no		-12 V	EVSE not available

[a] All voltages are measured after stabilization period, tolerance ±1 V.

[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 A.5.

[c] The voltage measured is function of the value of R3 in Figure A.1 (indicated as Re in Figure A.2).

[d] 12 V static voltage.

Typical start-up and shut-down sequence:

The Figure A.3 shows the sequence of a typical charging cycle under normal operating conditions. The sequences are detailed in Table A.4.

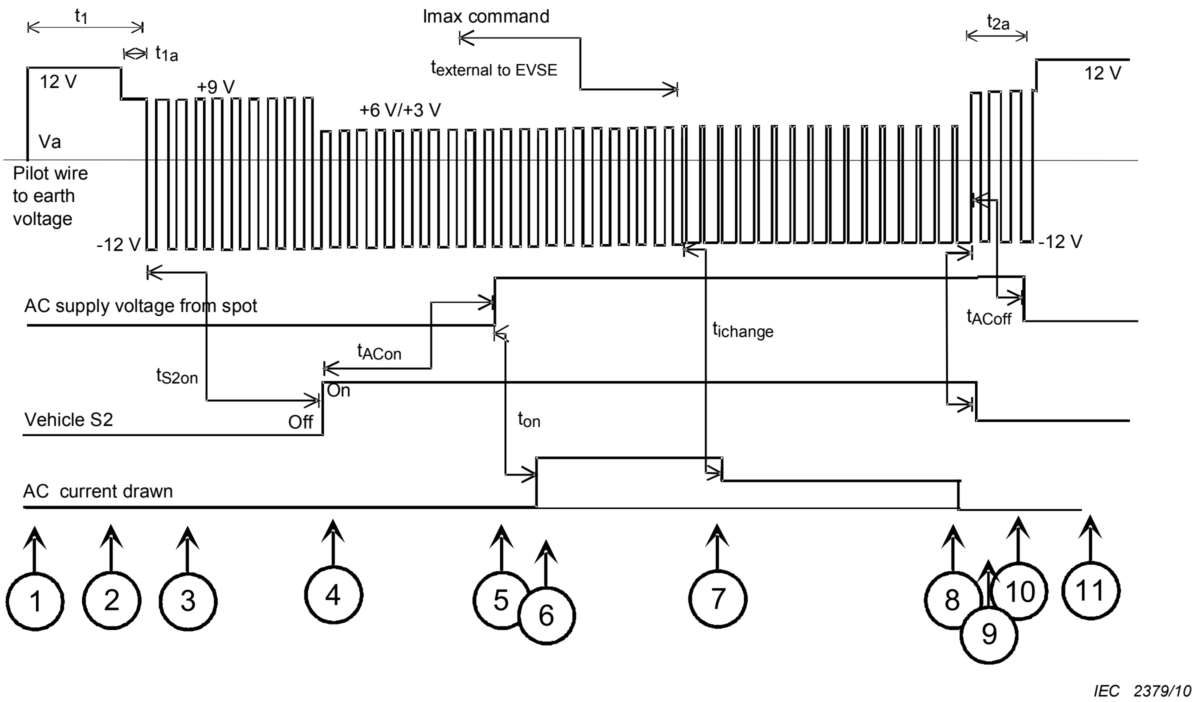


Figure A.3 – Typical charging cycle under normal operating conditions

Table A.4 – description of connecting sequences as shown on Figure A.3

	State	Conditions
1	A	Vehicle unconnected – the full generator voltage is measured by the EVSE at Va (see Figure A.1). The generator signal Vg is a +12 V DC voltage
2	B	The cable assembly is connected to the vehicle and to the EVSE. This condition is detected by the 9 V signal measured at Va. The voltage from the signal generator (Vg) may be either a steady state +12 V DC or a ±12 V, 1 kHz signal in conformity with Table A.1 if the EVSE is immediately available for the supply of energy.
3	B	The EVSE is now able to supply energy and indicated the available current to the vehicle by the duty cycle in conformity with Table A.5. The presence of the diode D (see Figure A.1) is detected by the – 12 V and gives added guarantee that the 9 V signal is a reliable indication of a vehicle connected.
4	B → C,D	S2 is closed by vehicle as a function of requirements to indicate that the vehicle can receive energy. There are no timing requirements for the closing of On.
5	C,D	EVSE closes circuit. The timing of switch closure may be subject other requirements (payment, data exchange). If state D is detected, the switch will close only if ventilation requirements are met.
6	C,D	Current drawn from the vehicle. The timing and current profile are determined by the vehicle. Current may not exceed that indicated by the duty cycle (Table A.5).
7	C,D	External demand for power reduction. Such a demand may originate from the grid or by manual setting on EVSE. The Vehicle adjusts the current demand to that indicated by the duty cycle.
8	C,D	End of charge, decided by the vehicle.
9	C,D →B	Vehicle asks for disconnect. This may be the result of the proximity contact being opened.
10	B	EVSE detects state B (created by opening of S2 on vehicle) and opens the contactor.
11	A	Complete removal of cable assembly from vehicle or EVSE is detected by the 12V signal.
NOTE The EVSE should allow removal of the plug if the end of the charging session is ended by entering state A.		

Table A.5 – Pilot duty cycle provided by EVSE

Available line current	Nominal duty cycle provided by EVSE (Tolerance ± 1 percentage point)
Digital communication will be used to control an off-board DC charger or communicate available line current for an on-board charger.	5 % Duty Cycle
Current from 6 A to 51 A:	(% duty cycle) = current[A] / 0,6 10 % ≤ duty cycle ≤ 85 %
Current from 51 A to 80 A:	(% duty cycle) = (current[A] / 2,5) + 64 85 % < duty cycle ≤ 96 %

Table A.6 – 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
3 % ≤ duty cycle ≤ 7 %	Indicates that digital communication will be used to control an off-board DC charger or communicate available line current for an on-board charger. Digital communication may also be used with other duty cycles. Charging is not allowed without digital communication. 5 % duty cycle shall be used if the pilot function wire is used for digital communication
7 % < duty cycle < 8 %	Charging not allowed
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
If the PWM signal is between 8 % and 97 %, the maximum current may not exceed the values indicated by the PWM even if the digital signal indicates a higher current.	

Table A.7 – EVSE timing (see Figure A.3)

t_1 and t_{1a}	No maximum	Turn on of 1 kHz oscillator	The frequency and voltage shall always conform to the values indicated in Table A.1
t_{ACon}	3 s	Beginning of supply of AC power after detection of state C or state D (vehicle request for energy) This time can be extended if there is digital communication established within this time	If conditions cannot be met EVSE should send one of following: steady state voltage 5 % PWM, state E or F
$t_{external}$	10 s	Modification of pulse-width in response to an external command to EVSE	The external command may be a manual setting or command from grid managements systems
t_{ACoff1}	100 ms maximum	Delay until contactor opens and terminates AC energy transfer in response to S2 opened	S2 will cause pilot voltage change which, when detected by EVSE causes opening of contactors
T_{2a}	No maximum	The state B is be maintained while the vehicle is connected provided the EVSE is capable of supplying further energy	The duty cycle shall indicate the current available as in Table A.5
$t_{ventilation}$ (not shown on Figure A.3)	3 s maximum	Delay for ventilation command turn on after transition from state C (6 V) to state D (3 V)	
Other conditions for termination of energy supply			
	3 s maximum	Delay for opening of contacts to terminate energy supply if abnormal conditions are encountered	This typically includes out of spec voltages of pilot, ventilation, non respect of current drawn (if measured by EVSE)
	3 s maximum	Delay for turning off the square wave oscillator after transition from state B,C or D to state A	
	100 ms maximum	Delay for opening contact if local proximity switch is opened	This applies to connectors using the proximity contact defined in B.4
	2 s maximum	Delay for applying a static 12 V signal after transition from state B, C or D, to state A.	
EV timing (see Figure A.3)			
T_{S2}	No maximum	S2 turn - request for AC supply	Determined by EV requirements
t_{on}	No maximum	Beginning of charging	The charging profile and timing are controlled by the vehicle. Ramp-up of current should only be possible when voltage is detected.
t_{ACoff2}	3 s maximum	Stop charger current draw, set S2 open if Pilot signal out of tolerance, state E or state F detected	Only applies to systems using complete pilot circuit described in Figure A.1
$t_{ichange}$	5 s maximum	Change of current following change in PWM duty cycle	
	100 ms	Delay for stopping charging current drawn by vehicle if proximity contact opened	Not shown on diagram

Annex B
(informative)

Example of a circuit diagram for a basic and universal vehicle coupler

B.1 General

This annex describes circuit diagrams for the mode 1, mode 2, and mode 3 charging methods using the basic interface (see Figures B.1 to B.5).

Mode 4 charging is presented with the universal vehicle coupler (see Figure B.7).

B.2 Circuits diagrams for mode 1, mode 2 and mode 3, using a basic single phase vehicle coupler

Clause B.2 of this annex shows the application of a single phase basic interface fitted with a switch on the proximity circuits.

Clause B.3 of this annex shows the application of a three phase basic interface that is not fitted with a switch on the proximity circuit, used for single and three-phase supply.

Components and functions in the circuit diagrams shown in Figures B.1 to B.5 are as follows.

The pilot function controller is located on the mains side.

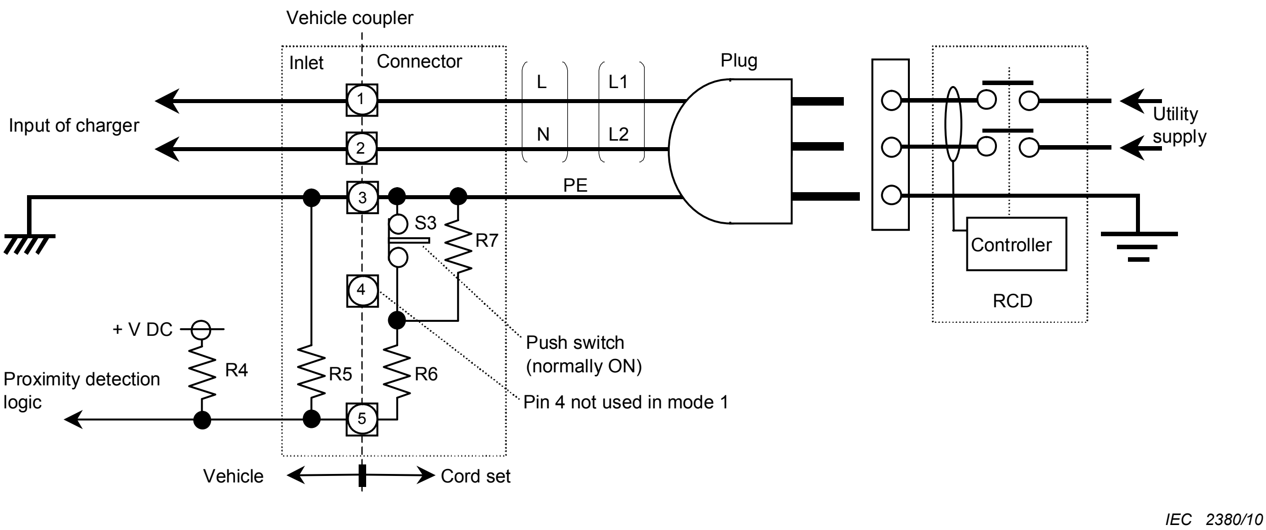
This circuit realizes the basic functions described in Annex A. The circuit is normally supplied from a low voltage source that is isolated from the mains by a transformer and contains a ±12 V 1 000 Hz pulse width modulated oscillator that indicates the power available from the socket.

Pilot function circuit:

Both mode 2 diagram shown in Figure B.2 and mode 3 diagram shown in Figures B.3 and B.4 have been drawn with a hard wired pilot functions as described in Annex A. The basic functions described in Annex A are represented by R1, R2, R3, D and S2 (see Figure A.1). The values indicated in Annex A should be used (see Table A.2) This function could also be achieved using the control function indicated in Annex C. The pin number 4 would not be used in this case.

Table B.1 – Identification of components used with basic single phase connector

	Name of component	Functions
1, 2	Phase and neutral contacts	Vehicle coupler power contacts
3	Earth protection contact	
4	Pilot function contact	
5	Proximity detection contact	Indicates the presence of the connector to vehicle. Used to signal correct insertion of the vehicle connector into the vehicle inlet. Can be used to avoid Un-intentional live disconnect (see Figure B.1 and Note).
R1,R2,R3, D,S1,S2,	Resistances, diodes and control switch	Components necessary for hard wired control pilot function
R4,R5,R6, R7,S3	Resistances and push button switch	Components necessary for proximity detection function
NOTE The auxiliary coupler contact can be used for un-intentional live disconnect avoidance using switch on vehicle connector. For this function, the push button is linked to a mechanical locking device. The depressing S3 un-locks the coupler and opens the circuit. The opening of S3 stops charging operation and contributes to prevention of un-intentional live disconnect. This function may also be achieved using proximity switches or contacts on the vehicle inlet cover or on the locking device		



NOTE 1 There is no pilot function in mode 1and pins 4 is not compulsory.

NOTE 2 In this drawing the switch S3 can be used for prevention of un-intentional live disconnect.

Figure B.1 – Mode 1 case B using the basic single phase vehicle coupler

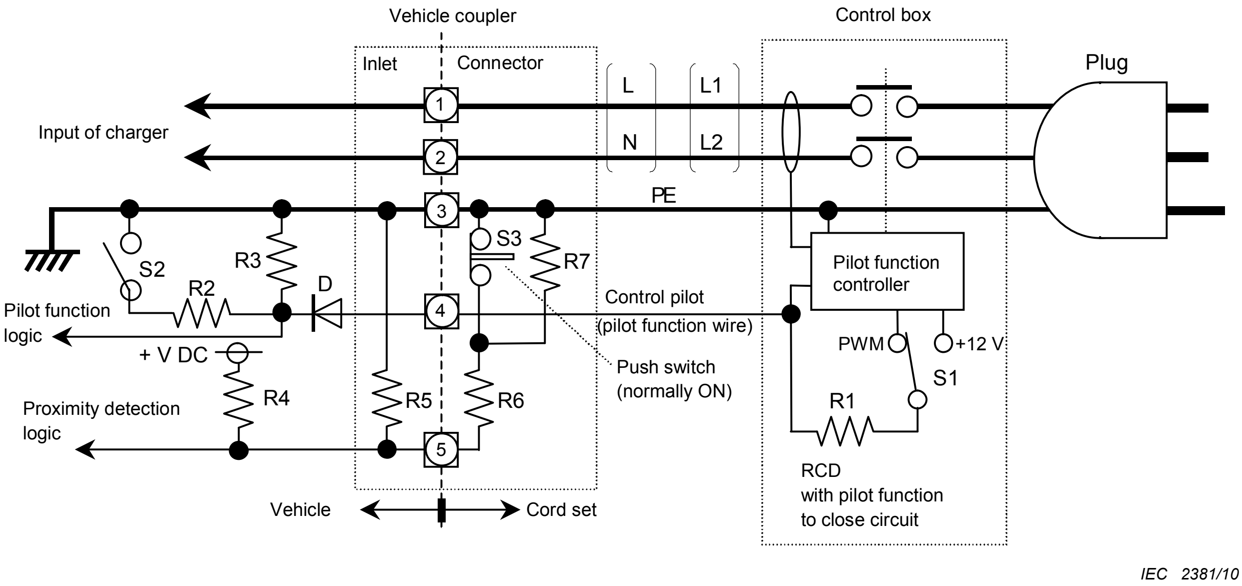


Figure B.2 – Mode 2 case B using the basic single phase vehicle coupler

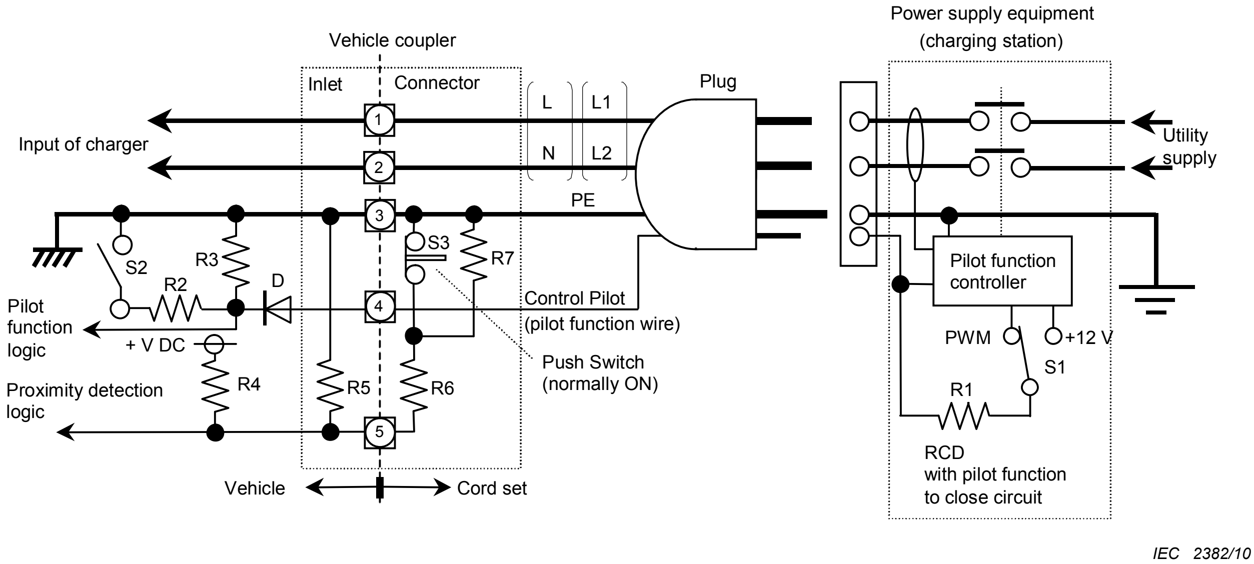


Figure B.3 – Mode 3 case B using the basic single phase vehicle coupler

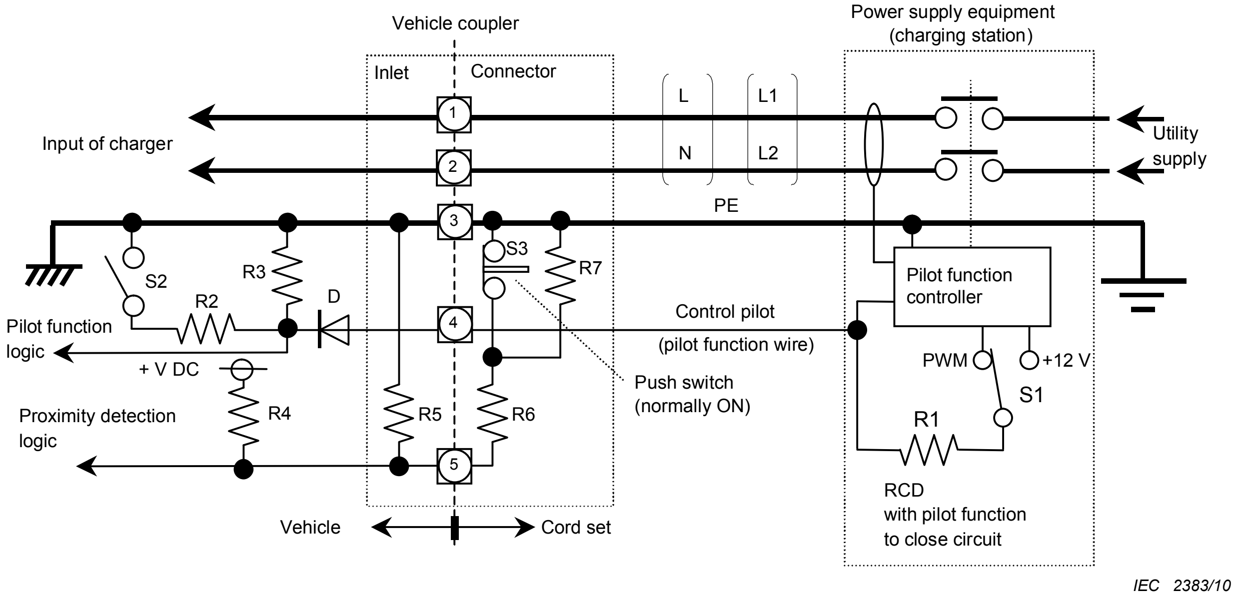


Figure B.4 – Mode 3 case C using the basic single phase vehicle coupler

B.3 Component values for all diagrams in Figures B.1 to B.5

Component values for all diagrams in Figures B.1 to B.5 are specified in Table B.2.

Table B.2 – Component values for all drawings

	Value	Tolerance
R1, R2, R3	As defined in Tables A.1 and A.2	
R4	330 Ω	± 10 %
R5	2 700 Ω	± 10 %
R6	150 Ω	± 10 %
R7	330 Ω	± 10 %
+V DC	Low voltage supply [a]	
[a] A +5 V regulated supply is recommended.		

B.4 Circuits diagrams for mode 3, using a basic single phase or three-phase accessory without proximity switch

Figure B.5 shows a three phase interface accessory that is used for either single phase or three phase supply. The same circuit diagram is also valid for single phase accessories. The current coding function described in B.4 is indicated. Values of the pull-up resistances and the Rc are indicated in Table B.3.

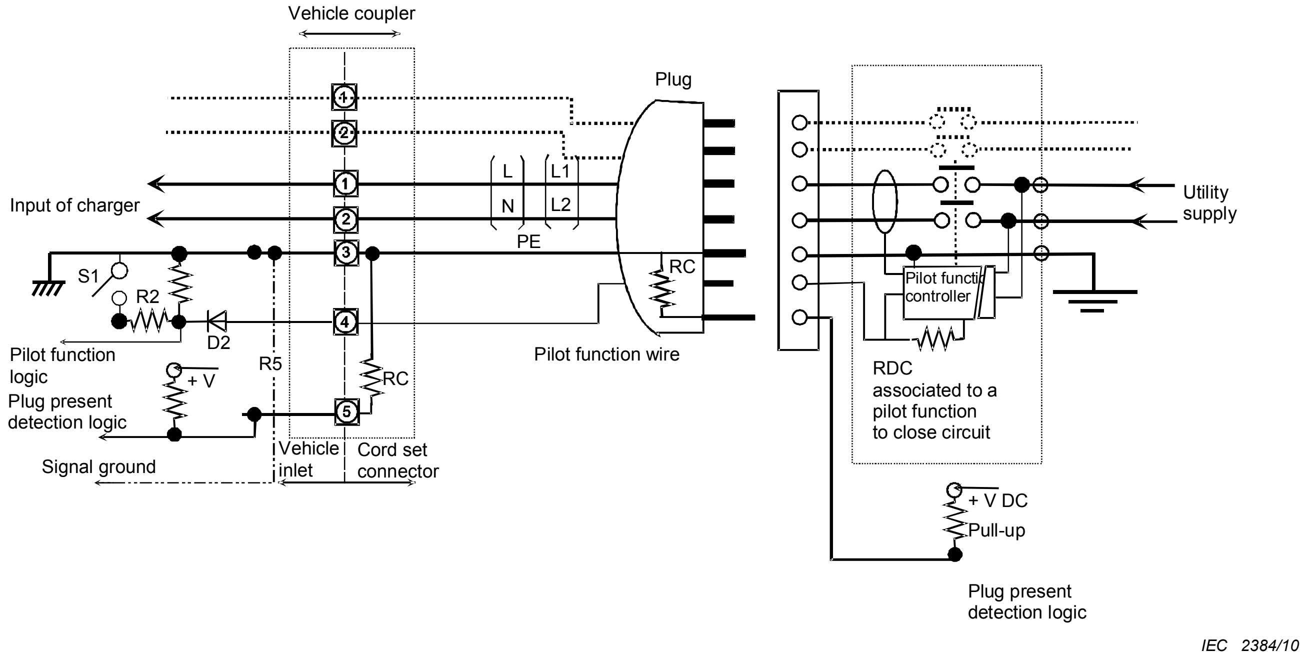


Figure B.5 – Mode 3 case B using the basic single phase vehicle coupler without proximity push button switch S3

NOTE The schemes indicated in Figures 1, 2 and 3 can also be realized with this connector provided the switch S3 is not required.

B.5 System for simultaneous proximity detection and current coding for vehicle connectors and plugs

Vehicle connectors and plugs using the proximity contact for simultaneous proximity detection and current capability coding of the cable assembly set shall have a resistor electrically placed between proximity contact and earthing contact (see Figure B.6) with a value as indicated in Table B.3.

The resistor shall be coded to the maximum current capability of the cable assembly.

The EVSE shall interrupt the current supply if the current capability of the cable is exceeded as defined by the value of Rc.

The resistor is also used for proximity detection.

Table B.3 – Resistor coding for vehicle connectors and plugs

Current capability of the cable assembly	Equivalent resistance of Rc Tolerance ± 3% [c]
13 A	1,5 kΩ 0,5 W [a, b]
20 A	680 Ω 0,5 W [a, b]
32 A	220 Ω 0,5 W [a, b]
63 A (3 phase) / 70 A (1 phase)	100 Ω 0,5 W [a, b]

[a] The power dissipation of the resistor caused by the detection circuit shall not exceed the value given above. The value of the pull-up resistor shall be chosen accordingly.

[b] Resistors used should preferably fail open circuit failure mode. Metal film resistors commonly show acceptable properties for this application.

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

Coding resistors, as indicated in Table B.3 shall be used in vehicle connectors and plugs, Type 2.

NOTE Type 2 vehicle connectors and plugs are being included in IEC 62196-2 (under development).

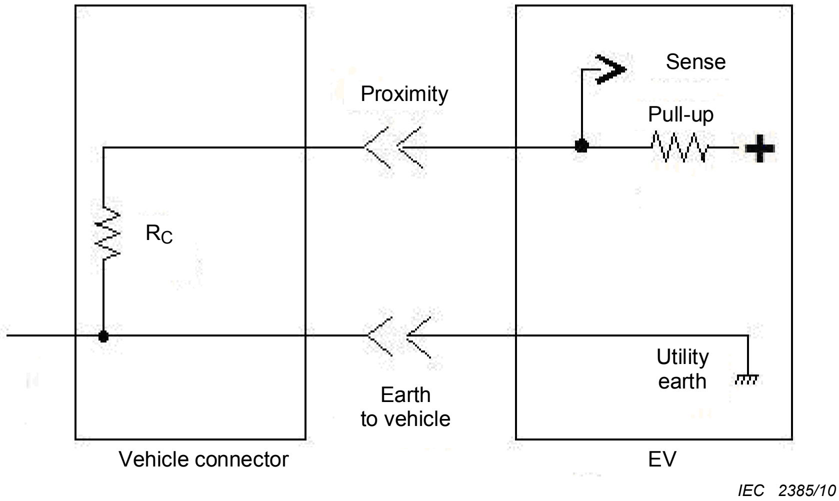


Figure B.6 – Diagram for current capability coding of the cable assembly

The same circuit diagram is used for the plug and EVSE outlet.

B.6 Circuit diagram for mode 4 connection using universal coupler

B.6.1 Parts list and function/characteristics

Parts list and function/characteristics in the circuit diagram for mode 4 connection are shown in Table B.4 and Figure B.7.

Table B.4 – Component description for Figure B.7 mode 4 case C

Reference	Parts list	Function/characteristics
A	Auxiliary contact	– detection of the connector – start for the on-board charger (option) – pilot circuit
BP	Locking release of the connector	– opens the pilot circuit to de-energize the system before the main contacts open: t > 100 ms
C1	Main contactor on the supply equipment	– closed on nominal operation if: 0,5 kΩ < R_o < 2 kΩ
C2 (option)	Main contactor on the vehicle	– closed on normal operation
E1	Auxiliary supply	– extra-low d.c. voltage to energize the pilot circuit: earth protection connector + pilot + chassis
D1	Diode	– not used – prevent the energization of the vehicle computer by the supply equipment
D2	Diode	– prevent the energization of the auxiliary supply circuit E1 and M1, by the vehicle
D3	Diode	– prevent short-circuit between the auxiliary supply E1 and the earth, inside the charging station

Reference	Parts list	Function/characteristics
FC (option)	Trap door close	– start for the on-board charger
G	Pilot contact (last closed during the connection)	– earth for detection of the connector – earth for the pilot circuit – clean data earth

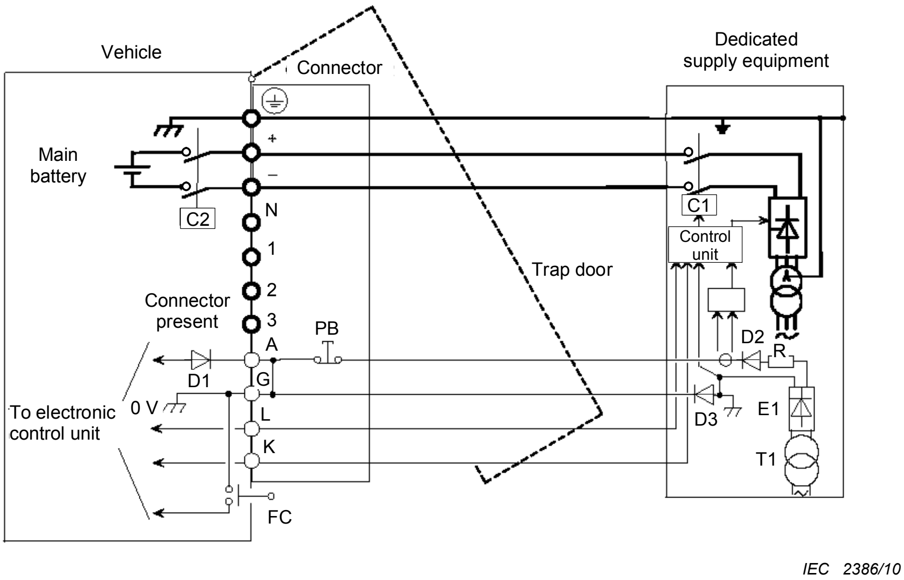


Figure B.7 – Mode 4 case C using the universal vehicle coupler