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Electrically propelled vehicles — Test specifications for lithium-ion battery systems combined with lead acid battery or capacitor

Véhicules routiers à propulsion électrique — Spécifications d'essai pour les systèmes de batteries aux ions lithium couplées à d'autres types de batterie ou condensateur

Reference number
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Foreword

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The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

Introduction

High-performance on-board electric energy storage is the main obstacle in developing electric vehicles available at more affordable prices. In order to ensure high efficiency and good motion properties, there are many requirements imposed on electrical energy storage sources, such as high power and energy density, long cycle and calendar life, reliability, wide temperature range and no emission of pollutants. The most common energy storages/sources in electric vehicles are electrochemical batteries and electric double layer capacitor. However, installing only one type of energy storage/source could be insufficient to complement each single type drawbacks. Hybridization of the source enables to solve some key problems encountered in electric vehicles such as regenerative braking, while the main source of energy is lithium-ion battery.

Today's hybrid electrical vehicles (HEVs), for example, use rechargeable batteries with gasoline-powered engines to provide power to a vehicle. This system uses the battery as a power buffer to support the engine in order to achieve greater gas mileage. While using a battery in an HEV by itself, the battery is subjected to changes in the amount of power it generates and receives from the load. Since most rechargeable batteries have low-power densities, their life spans are reduced by constant erratic oscillation in demand. A solution to this problem can be dual battery system or two batteries system or combined system with electric double layer capacitor. By using additional energy storage systems, battery performance improvement can be achieved.

The hybrid lithium-ion battery system can supplement the traditional 12V electrical network with a 48V electrical system and components, bridging the gap between low-end hybridization based on present-day 12V start-stop systems. Many hybrids sold will be expected microhybrids, those using start-stop and brake regeneration technologies that operate either with the existing 12V vehicle electric system or with a combined 12V and 48V dual battery/dual voltage electric system. These relatively inexpensive start-stops can provide limited hybrid power assist on launching and also for energy regeneration during braking.

The purpose of this document is the description of such a voltage class A electric system.

Electrically propelled vehicles — Test specifications for lithium-ion battery systems combined with lead acid battery or capacitor

1 Scope

This document specifies the lithium-ion battery systems combined with lead acid battery or electric double layer capacitor to be used for automotive applications in voltage class A systems. document applies only to combinations of such electric energy storages that are integrated in a common housing.

It specifies configurations, test procedures, and requirements for such combinations.

2 Normative references

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

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 8713 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
assistance battery
battery that temporarily supports the main battery

3.2
assistance capacitor
electric double layer capacitor energy storage system that temporarily supports the role of the main battery

3.3
battery
one or more cells fitted with devices necessary for use, for example, case, terminals, marking and protective devices

3.4
battery control unit
BCU
electronic device that controls or manages or measures or calculates electric and thermal functions of the battery system and that provides communication between the battery system and other vehicle controllers

3.5
capacity
C
total number of ampere-hours that can be withdrawn from a fully charged battery under specified conditions of main battery

3.6
customer
party which is interested to use the battery pack or system and therefore order or perform the test

3.7
device under test
DUT
lithium-ion battery pack or system combined with lead acid battery and capacitor

3.8
electric double layer capacitor
EDLC
device for electrostatic storage of electrical energy achieved by separation of charge in a double layer

3.9
electric double layer capacitor energy storage system
energy storage devices that include capacitors or capacitor assemblies or capacitor packs as well as electrical circuits and electronics

3.10
lithium-ion cell
secondary single cell whose electrical energy is derived from the insertion/extraction reactions of lithium ions between the anode and the cathode

Note 1 to entry: The secondary cell is a basic manufactured unit providing a source of electrical energy by direct conversion of chemical energy. The cell consists of electrodes, separators, electrolyte, container and terminals, and is designed to be charged electrically.

Note 2 to entry: In this document, cell or secondary cell means the secondary lithium-ion cell to be used for the propulsion of electric road vehicles.

3.11
lithium-ion battery pack
battery pack
energy storage device that includes cells or cell assemblies normally connected with cell electronics and overcurrent shut-off device including electrical interconnections and interfaces for external systems

Note 1 to entry: Examples for interfaces are cooling, high voltage, auxiliary low voltage and communication.

3.12
lithium-ion battery system
battery system
energy storage device that includes cells or cell assemblies or battery pack(s) as well as electrical circuits and electronics

EXAMPLE BCU, contactors.

3.13
main battery
lithium-ion battery pack or system that mainly supplies electrical energy continuously

3.14
room temperature
RT
temperature of (25 ± 2) °C

3.15
micro-cycle
charge and discharge cycle within 60 s

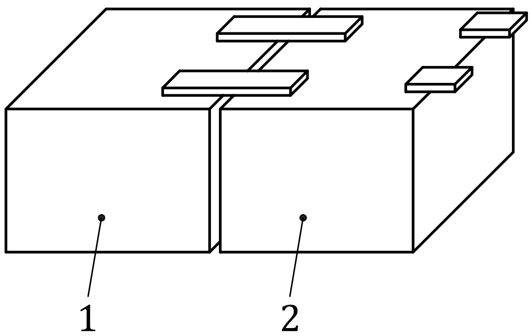
4 Abbreviated terms

LICA	Lithium-ion battery pack or system combined with electric double layer capacitor
LIPB	Lithium-ion battery pack or system combined with lead acid battery

5 Type of connection with lithium-ion battery system

5.1 Lithium-ion battery pack or system combined with lead acid battery (LIPB)

The lithium-ion battery pack or system combined with lead acid battery (LIPB) is composed of the lithium-ion battery pack or system as main battery and the lead acid battery as assistance battery. The main battery and the assistance battery are connected by mechanical and electrical connecting bars as shown in Figure 1. See also Annex A including Figures A.2, A.3, and A.4 for more detailed information.



Key

1 main battery (lithium-ion battery system)

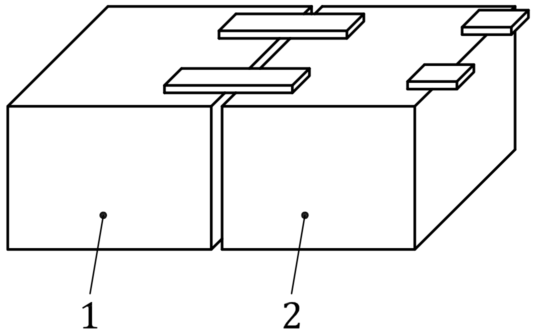
2 assistance battery (lead acid battery)

NOTE There are several connection methods possible; the display in this Figure is only schematically.

Figure 1 — Type of configuration of LIPB

5.2 Lithium-ion battery pack or system combined with electric double layer capacitor energy storage system (LICA)

The lithium-ion battery pack or system combined with electric double layer capacitor energy storage system (LICA) is composed of the lithium-ion battery pack or system as main battery and the electric double layer capacitor energy storage system as assistance capacitor. The main battery and the assistance capacitor are connected by mechanical and electrical connecting bars as shown in Figure 2. See also Annex A for more information.



Key

1 main battery (lithium-ion battery system)

2 assistance battery (assistance capacitor)

NOTE There are several connection methods possible; the display in this Figure is only schematically.

Figure 2 — Type of configuration of LICA

6 General requirements

DUT shall fulfil the following requirements:

— Necessary documentation for operation and needed interface parts for connection to the test equipment (i.e. connectors, plugs including cooling) shall be delivered together with the DUT.

DUT shall enable the specified tests, i.e. via specified test modes implemented in the BCU and shall be able to communicate with the test bench via common communication buses.

If not otherwise specified, before each test, the DUT shall be stabilized at the test temperature for a minimum of 12 h and the BCU, if any, shall be switched off. This period may be reduced if the thermal stabilization of the DUT is reached. Thermal stabilization is fulfilled when after a period of 1 h, the temperature difference among all available cell temperature measuring points is within 4 K.

If not otherwise specified, each charge and each SOC change shall be followed by a rest period of 30 min.

The accuracy of external measurement equipment shall be at least within the following tolerances:

— voltage ±0,5 %;

— current ±0,5 %;

— temperature ±1 K.

The overall accuracy of externally controlled or measured values, relative to the specified or actual values, shall be at least within the following tolerances:

— voltage ±1 %;

— current ±1 %;

— temperature ±2 K;

— time ±0,1 %;

— mass ±0,1 %;

— dimensions ±0,1 %.

All values (time, temperature, current and voltage) shall be noted at least every 5 % of the estimated discharge and charge time, except if it is noted otherwise in the individual test procedure.

7 Test for LIPB

7.1 Pre-conditioning

7.1.1 Purpose

The DUT shall be conditioned by performing charge and discharge three times, before starting the real testing sequence, in order to ensure an adequate stabilization of the complete system. The pre-conditioning cycles shall be defined by the manufacturer.

7.1.2 Procedure

7.1.2.1 General

The standard cycle (SC) shall be performed at RT. The SC shall comprise a standard discharge, in 7.1.2.2, followed by a charge (see 7.1.2.3). If, for any reason, the time interval between the end of the SC and the start of a new test is longer than 3 h, the SC shall be repeated.

7.1.2.2 Standard discharge

— The device energy capability of the DUT is given in watt-hours at a constant power discharge rate as agreed between supplier and customer.

— Discharge is terminated at a discharge voltage limit as specified by the manufacturer.

7.1.2.3 Standard charge

Charge procedure and end-of-charge criteria:

— According to the specifications given by the supplier, the specifications shall cover end-of-charge criteria and time limits for the overall charging procedure.

— Rest period after charge to reach the stable condition is 30 min.

7.2 Rated capacity

7.2.1 Purpose

This test is intended to measure the capacity expressed in Ah of system. The rated capacity shall be the 1 h capacity at a temperature of 25 °C declared by the manufacturer.

7.2.2 Procedure

The test shall be performed at RT.

Discharge phase:

— Constant current with the following discharge rate: 1C and 1/3C rate as permitted by the supplier (the maximum C rate corresponds with I_{max}).

Charge phase:

— Before starting the charge phase, the DUT shall rest at least for 30 min or shall reach RT.

— The charge phase shall not be started until the temperature of the pack or system is fully equilibrated to the proper charge temperature, or a fixed equilibration time period shall be used to allow for full equilibration of the DUT.

After a discharge phase, the DUT shall rest at least for 30 min or shall reach RT before starting the charge phase. See Table 1.

Table 1 — Rated capacity test procedure

Step	Procedure	Ambient temperature
1.1	Discharge at 1C	RT
1.2	Charge	RT
1.3	Standard cycle (SC)	RT
1.4	Discharge at 1/3C	RT
1.5	Charge	RT
2.1	Standard cycle (SC)	RT

The battery conditioning shall be discontinued at the first cycle where the rated capacity is achieved. If the battery fails to meet the rated value within 10 cycles, the testing is discontinued.

7.3 Micro-cycle test

7.3.1 Purpose

In electrified vehicle systems, propulsion battery system shall be capable of supplying widely varying current rates. The driving profiles can be simplified to high-rate current for acceleration, low-rate current for constant speed driving and zero current for rest periods.

The objective of this test is to determine the number of micro-cycles of LIPB by using the simplified driving profile.

7.3.2 Micro-cycle without regenerative charging

The micro-cycle without regenerative charging shall be represented by a 60 s repeated three current levels.

— I_{dh} (A) high-rate current discharging pulse

— I_{dl} (A) low-rate charging pulse

— I_0 (A) zero current

NOTE The discharge current of high rate or low rate is agreed between supplier and customer.

7.3.2.1 Procedure

The procedure shall be the following.

— The test shall be performed at RT.

— The energy capability of the DUT is given in watt-hours at a constant power discharge rate as agreed between supplier and customer.

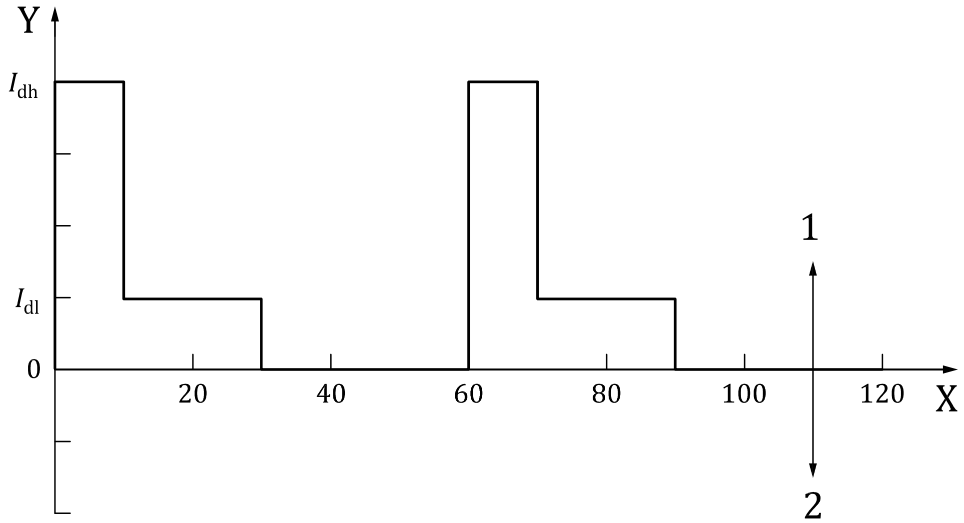
— Discharge is terminated at a discharge voltage limit as specified by the manufacturer.

See Table 2.

Table 2 — Micro-cycle without regenerative charging test procedure

Step	Procedure	Time s	Accumulated time s	Current (A)	Ambient temperature
1.1	Thermal equilibrium				RT
1.2	Discharge	10 s	10	I_{dh}	RT
1.3	Discharge	20 s	30	I_{dl}	RT
1.4	Rest	30 s	60	I_0	RT
2.1	Discharge	10 s	70	I_{dh}	RT
2.2	Discharge	20 s	90	I_{dl}	RT
2.3	Rest	30 s	120	I_0	RT

The micro-cycle procedure shall be determined by three subsequent micro-cycles (see Figure 3) repeated after 60 s.



Key

1 discharge

2 charge

Y current (A)

X time (s)

Figure 3 — Test profile without regenerative charging

7.3.3 Micro-cycle with regenerative charging

The micro-cycle with regenerative charging shall be represented by a 65 s repeated four current levels.

— I_{dh} (A) discharge

— I_{dl} (A) discharge

— I_{rc} (A) recharge

— I_0 (A) zero current

NOTE The discharge current of high rate or low rate is agreed between supplier and customer.

7.3.3.1 Procedure

The procedure shall be the following.

— The test shall be performed at RT.

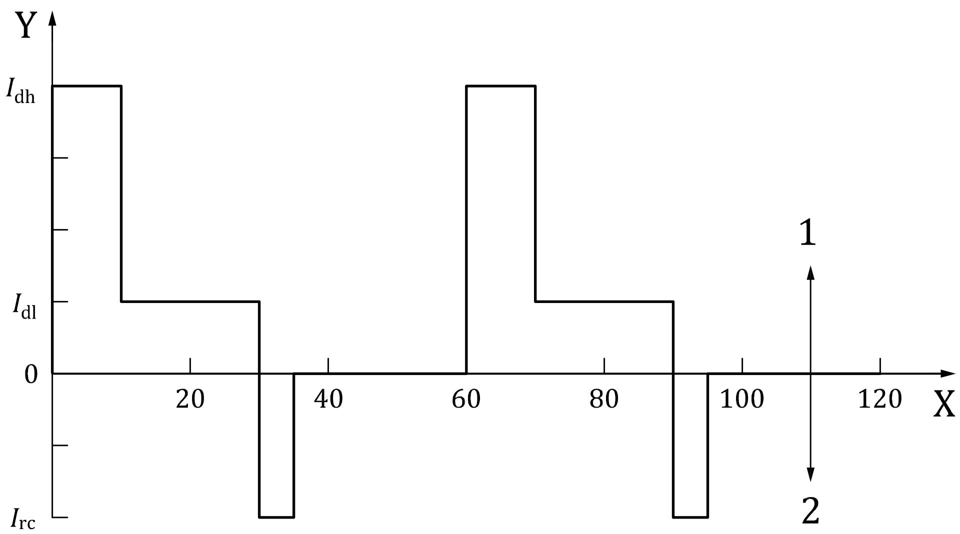
— The energy capability of the DUT is given in watt-hours at a constant power discharge rate as agreed between supplier and customer.

— Discharge is terminated at a discharge voltage limit as specified by the manufacturer.

See Table 3 and Figure 4.

Table 3 — Micro-cycle with regenerative charging test procedure

Step	Procedure	Time s	Accumulated time s	Current (A)	Ambient temperature
1.1	Thermal equilibrium				RT
1.2	Discharge	10 s	10	I_{dh}	RT
1.3	Discharge	20 s	30	I_{dl}	RT
1.4	Recharge	5 s	35	I_{rc}	RT
1.5	Rest	30 s	65	I_0	RT
2.1	Discharge	10 s	75	I_{dh}	RT
2.2	Discharge	20 s	95	I_{dl}	RT
2.3	Recharge	5 s	100	I_{rc}	RT
2.4	Rest	30 s	130	I_0	RT



Key

1 discharge

2 charge

Y current (A)

X time (s)

Figure 4 — Test profile with regenerative charging

7.4 Cycle life test

7.4.1 Purpose

The cycle life test shall be performed to determine the charge and discharge life of LIPB.

7.4.2 Procedure

— The test shall be performed at RT.

— After a discharge phase, the DUT shall rest at least for 30 min or shall reach RT before starting the charge phase.

— The cycle life test shall be terminated when the energy delivered falls to below 80 % of the reference energy content.

See Table 4.

Table 4 — Cycle life test procedure

Step	Procedure	Ambient temperature
1.1	Thermal equilibrium	RT
1.2	Charge	RT
1.3	Standard cycle (SC)	RT
1.4	Discharge at 1C	RT
2.1	Charge	RT
2.2	Standard cycle (SC)	RT
2.3	Discharge at 1C	RT

7.4.3 Requirement

The number of reference test cycles shall be recorded and declared as the battery life.

8 Tests for LICA

8.1 Pre-conditioning

8.1.1 Purpose

The DUT shall be conditioned by performing charge and discharge three times, before starting the real testing sequence, in order to ensure an adequate stabilization of the complete system. The pre-conditioning cycles shall be defined by the manufacturer.

8.1.2 Procedure

8.1.2.1 General

The standard cycle (SC) shall be performed at RT. The SC shall comprise a standard discharge, in 8.1.2.2, followed by a charge (see 8.1.2.3). If, for any reason, the time interval between the end of the SC and the start of a new test is longer than 3 h, the SC shall be repeated.

8.1.2.2 Standard discharge

— The device energy capability of the DUT is given in watt-hours at a constant power discharge rate as agreed between supplier and customer.

— Discharge is terminated at a discharge voltage limit as specified by the manufacturer.

8.1.2.3 Standard charge

— According to the specifications given by the supplier, the specifications shall cover end-of-charge criteria and time limits for the overall charging procedure.

— Rest period after charge to reach the stable condition is 30 min.

8.2 Micro-cycle with regenerative test

8.2.1 Purpose

In electrified vehicle systems, propulsion battery system shall be capable of supplying widely varying current rates. The driving profiles can be simplified to high-rate current for acceleration, low-rate current for constant speed driving and zero current for rest period.

The objective of this test is to determine the number of micro-cycles of LICA by using the simplified driving profile.

8.2.2 Procedure

The procedure shall be the following.

— The test shall be performed at RT.

— The energy capability of the DUT is given in watt-hours at a constant power discharge rate as agreed between supplier and customer.

— Discharge is terminated at a discharge voltage limit as specified by the manufacturer.

The micro-cycle with regenerative charging shall be represented by 65 s repeated four current levels.

— I_{dh} (A) discharge

— I_{dl} (A) discharge

— I_{rc} (A) recharge

— I_0 (A) zero current

NOTE The discharge current of high rate or low rate is agreed between supplier and customer.

8.3 Cold cranking power

8.3.1 Purpose

The cold cranking power test is intended to measure power capability at low temperature. The aim is to generate a data basis for time-dependent power output at low temperatures.

8.3.2 Procedure

This test for cranking power at −18 °C shall be performed at the permitted SOC level as specified by the supplier according to the test sequence in Table 5.

Table 5 — Test sequence cold cranking power at −18 °C

Step	Procedure	Ambient temperature
1.1	Thermal equilibrium	RT
1.2	Standard charge	RT
1.3	Standard cycle	RT
1.4	Discharge the fully charged DUT at a 1C discharge rate to 20 % SOC or the minimum SOC specified by the supplier	−18 °C
1.5	Thermal equilibrium	−18 °C
1.6	Set constant voltage of the bench to the lowest permitted system discharge voltage level according to the supplier recommendation for 2 s and monitor the power versus time profile. The maximum current shall not exceed the supplier specification.	−18 °C
1.7	Rest period with open circuit for 10 s	−18 °C
1.8	Repeat step 1.6 to 1.7 twice	−18 °C
1.9	Thermal equilibrium	RT
1.10	Standard charge	RT

The sampling rate for test data during the test shall be ≤50 ms. If agreed between supplier and customer, the test for cranking power shall also be performed at −30 °C at the lowest SOC level permitted as specified by the supplier according to the test sequence in Table 6.

Table 6 — Test sequence cold cranking power at −30 °C

Step	Procedure	Ambient temperature
1.1	Thermal equilibrium	RT
1.2	Standard charge	RT
1.3	Standard cycle	RT
1.4	Discharge the fully charged DUT rate at a 1C discharge rate to 20 % SOC or the lowest SOC level allowable as specified by the supplier (minimum state of charge)	−30 °C
1.5	Thermal equilibration	−30 °C
1.6	Set constant voltage of the bench to the lowest permitted system discharge voltage level according to the supplier recommendation for 2 s and monitor the power versus time profile. The maximum current shall not exceed the supplier specification.	−30 °C
1.7	Rest period with open circuit for 10 s	−30 °C
1.8	Repeat step 1.6 to 1.7 twice	−30 °C
1.9	Thermal equilibrium	RT
1.10	Standard charge	RT

8.3.3 Requirement

The test result shall be delivered as graphic present of power versus time profiles including current, voltage and temperature values.

Annex A
(informative)

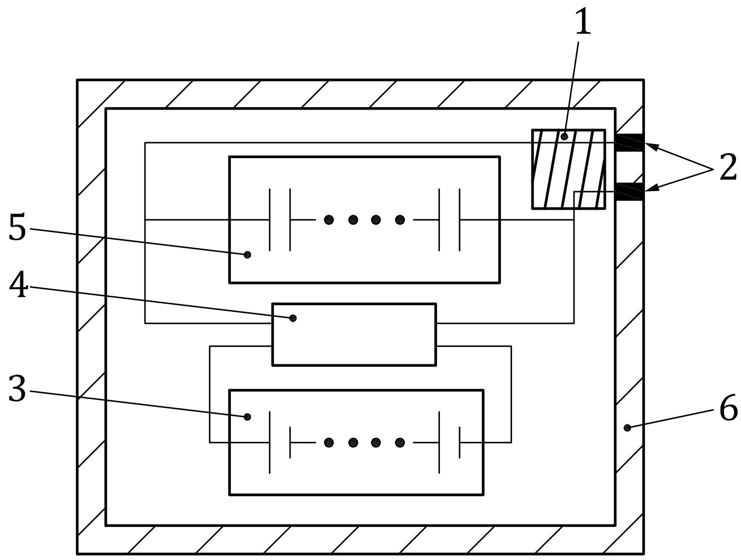
LICA and LIPB

A.1 General

This Annex provides information on the configuration of lithium-ion battery system combined with lead acid battery (LIPB) or electric double layer capacitor (LICA).

A.2 Lithium-ion battery system combined with electric double layer capacitor

In Figure A.1, the electric double layer capacitors model connects via a half-bridge converter (e.g. buck-boost stage consisting of line reactor and a phase leg module) to the lithium-ion cell model. Figure A.2 shows the active parallel combination case and the capacitor pack/system connected via a half-bridge converter (e.g. buck-boost stage consisting of line reactor Lbb and a phase leg module) to the lithium-ion battery system.



Key

1 electric circuit (fuse, wiring)

2 connections

3 lithium-ion battery

4 converter

5 electric double layer capacitor storage systems

6 case

Figure A.1 — Example of parallel connection of lithium-ion battery and capacitor

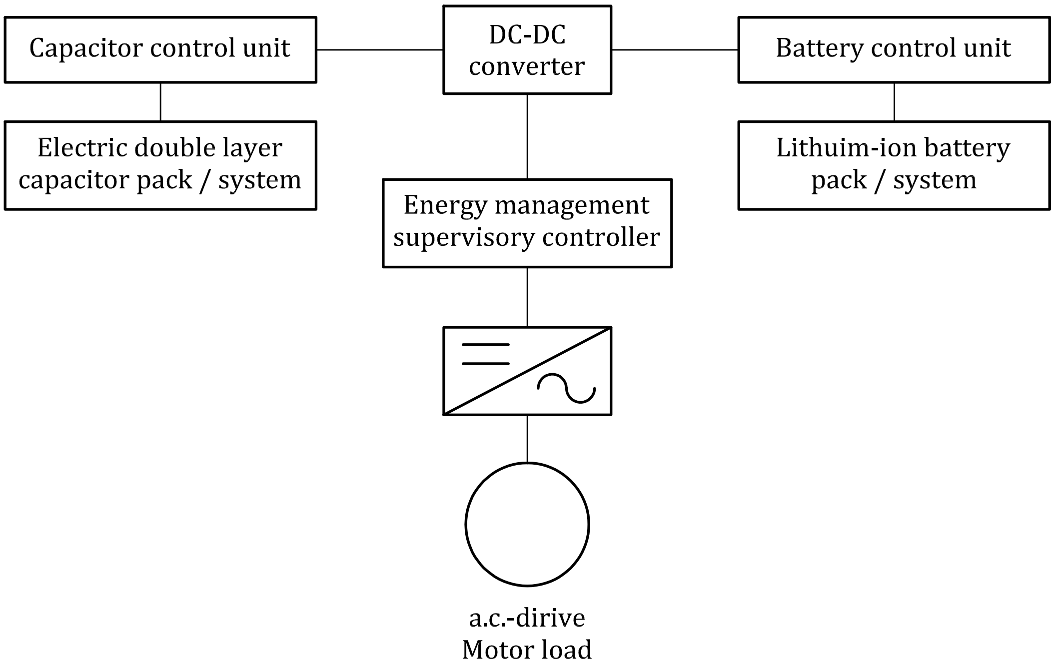
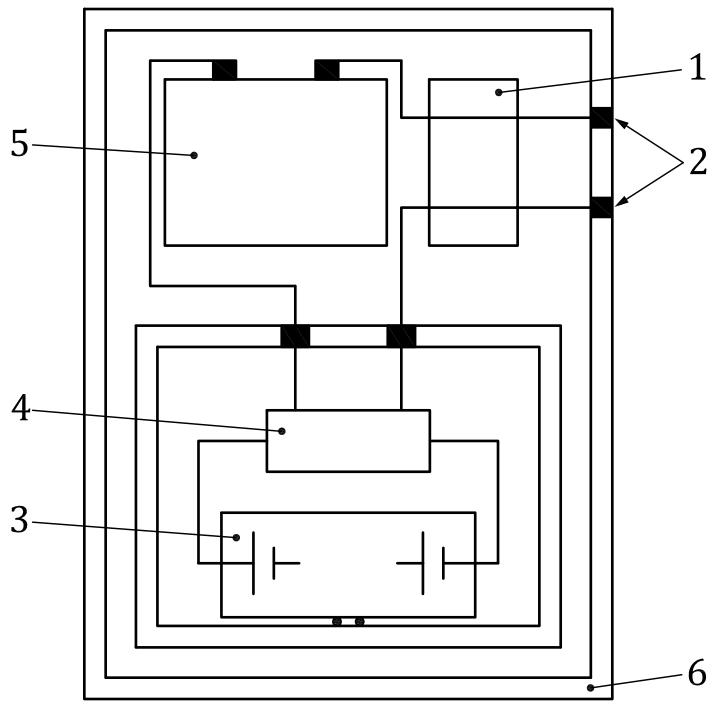


Figure A.2 — Power electronic interface for an electric double layer capacitor as the power buffer in a hybrid electric energy storage system

A.3 Lithium-ion battery system combined with lead acid battery

Examples of LIPB are shown in Figure A.3 and Figure A.4. LIPB as shown in Figure A.4 supplements the traditional 12V electrical network with a 48V electrical system and components.



Key

1 electric circuits (fuse, wiring)

2 connections

3 lithium-ion battery

4 battery control unit

5 lead acid battery

6 case

Figure A.3 — Example of parallel connection of lithium-ion battery and lead acid battery

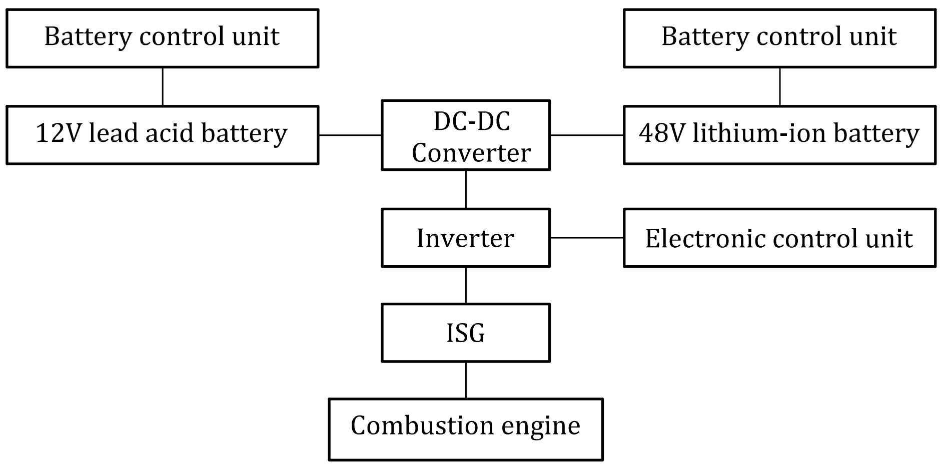


Figure A.4 — 48V drive system

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